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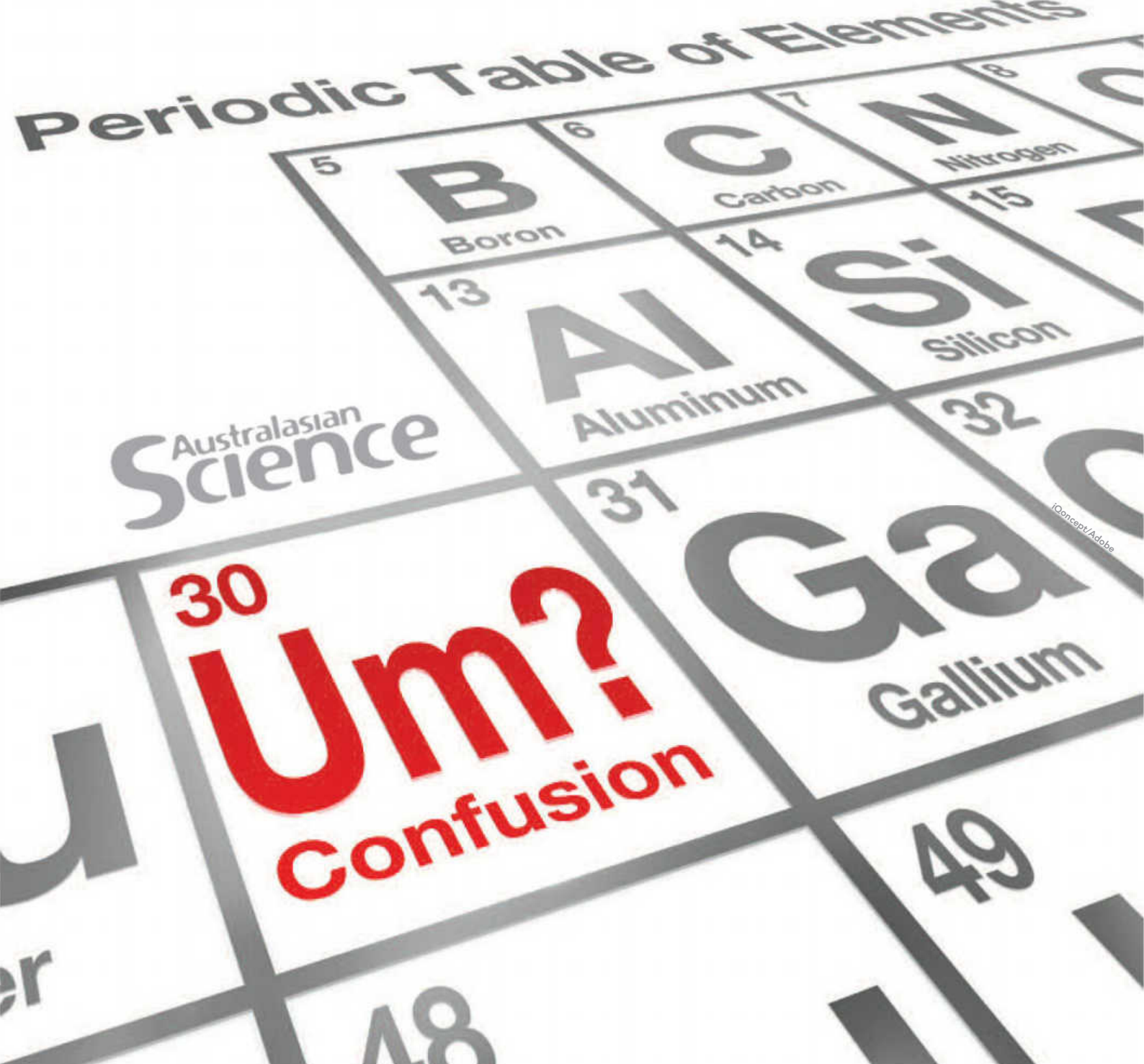
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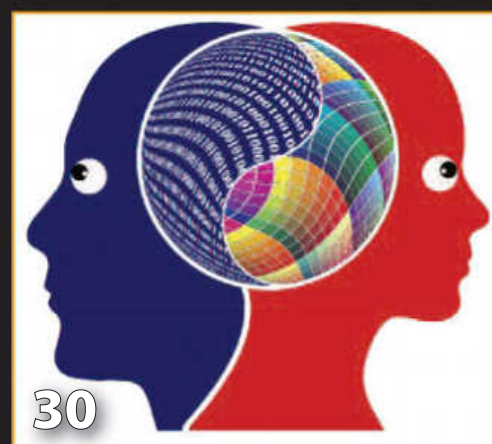
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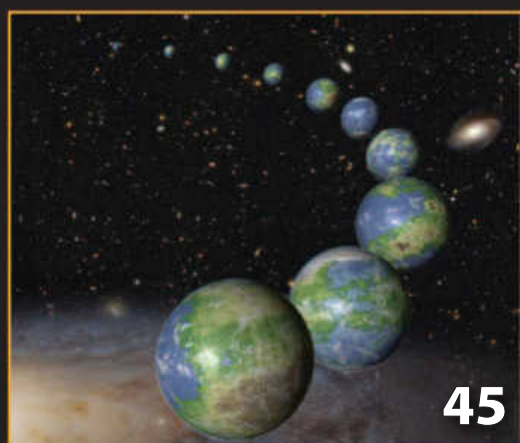
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CSIRO Weathers a New Storm

CSIRO's climate scientists are used to being gagged and bound, but now they have also been thrown overboard.

The summer just ended has been torrid for many scientists. While some were sweating through the task of writing grant proposals to fund their research programs, an ill wind was blowing for CSIRO's climate scientists.

Dr Larry Marshall took over the helm of CSIRO in January 2015 after a career as a technology entrepreneur in which, according to his staff profile, he "founded six successful United States companies in biotechnology, photonics, telecommunications and semi-conductors". These start-ups must seem like nimble speedboats compared with the *Titanic*-sized CSIRO, which has been slowly steered away from its weighty history of public service by corporate captains charting more profitable waters.

Marshall justified the staffing cuts in its land, water, oceans and atmosphere divisions by saying that the question of climate science had been answered. Now, he reasoned, CSIRO's capacity needed to be redeployed to develop ways to adapt to climate change.

But this treats climate as one homogenous entity. It ignores regional climate differences and the fact that climate is changing, and with it extreme climate-related events. Watch out for that iceberg!

Australia is a land of drought and flooding rains. We sit largely isolated at the bottom of the planet surrounded by tropical, temperate and polar oceans. The climate is changing differently within our continent, let alone compared with the rest of the world.

We can't adequately plan for climate mitigation without continuously monitoring our regional climate and modelling the climate events we will need to mitigate against. Why outsource this expertise when there is still so much we need to know about how this sunburnt country, the oceans that surround it and the atmosphere above affect regional and even global climate? Who will be left to give evidence-based advice to counter the vested business interests that so influence our political leaders?

The Federal government has a long history of climate denial, with climate scientists famously gagged from public comment during the previous decade. Indeed the blatant climate denial dogma of the Abbott government still hangs in Canberra's air.

A spokesman for Science Minister Christopher Pyne passed off the current tempest as "an operational decision of the CSIRO". That's not good enough. As Science Minister, Pyne shouldn't be spectating. CSIRO is a core component of his responsibilities.

Among the primary roles recognised in CSIRO's Charter is to "further the interests of the Australian community". Who could argue the central importance to the nation of Australia's land, water, oceans, atmosphere and climate?

The Science Minister and CSIRO's Board set Marshall's course. They need to steer this in the Australian community's interest.

Guy Nolch is Editor/Publisher of *Australasian Science*.



Cover Story

Last year the UK became the first country to permit the transfer of healthy mitochondria into the egg of a woman to prevent the inheritance of mitochondrial disease by her child. Current regulations in Australia are unlikely to allow this treatment to be used clinically, but are there any valid ethical reasons why this should continue to be the case? Image credit: nobeastsofierce

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Weekend Treats Undo Healthy Weekdays

Eating well during the week only to binge on junk food over the weekend is likely to be just as bad for your gut health as a consistent diet of junk, according to a study of the gut microbiota of rats.

The human gut consists of up to 100 trillion microbial cells that influence metabolism, nutrition and immune function. Disruption of this microbiota has been linked with gastrointestinal conditions such as inflammatory bowel disease and obesity.

The new study, published in *Molecular Nutrition and Food Research* (tinyurl.com/zoqjbvk), indicates that “intermittent exposure to junk food 3 days a week is sufficient to extensively shift the gut microbiota towards the pattern seen in obese rats consuming the diet continuously,” said Prof Margaret Morris of The University of NSW. “While these findings are yet to be replicated in humans, those who are strict with their diet during the week may be undoing all their good work by hitting the junk food over the weekend.”

The research team compared the abundance of microbiota in rats given continuous access to either a healthy diet or junk food with a group that alternated between four healthy days and three junk food days. A range of metabolic markers, including body weight, fat mass, insulin and leptin, were also examined.

At the end of 16 weeks, rats on the alternating diet were 18% heavier than those on the healthy diet, while leptin and insulin levels in these rats were in between rats fed junk or healthy food.

The researchers found that the microbiota of rats on the alternating diet was almost indistinguishable from rats fed a constant diet of junk, with the microbiota of both groups significantly different from rats fed a healthy diet.

The junk food diet also reduced the abundance of microbial species capable of metabolising flavonoids, which assist in weight loss and exert neuroprotective functions within the brain.

Rats on the alternating diet also varied greatly in their food



intake, consuming 30% more energy than those maintained on the healthy diet only. When the rats switched back to a healthy diet, they consumed half as much food as those maintained on a healthy diet only.

Morris said that a greater understanding of the role of energy-rich foods and dieting on microbial changes is important given the current obesity epidemic and the prevalence of yo-yo dieting in Western countries. “The study suggests certain gut microbiota, including *Ruminococcus* and *Blautia*, may be promising targets for future therapeutic strategies to treat metabolic disorders,” she said.

Food Allergy Linked to Hyperactive Immune System at Birth

Babies with hyperactive immune cells at birth, detected in their cord blood, are more likely to develop food allergies in their first year of life. The finding, published in *Science Translational Medicine* (tinyurl.com/zmfu9ov), could lead to future treatments that prevent childhood food allergies.

Prof Len Harrison of the Walter and Eliza Hall Institute (WEHI) said that the study of the cord blood of more than 1000 newborns “found a link between children who had hyperactive immune cells at birth and the development of allergies to milk, eggs, peanuts, wheat and other common foods in their first years of life”.

Lead author Dr Yuxia Zhang of WEHI said that babies at risk of developing food allergies had activated immune cells at birth. “In at-risk babies, immune cells called monocytes were activated before or during birth. Signals from these cells encouraged the development of immune responses by specialised immune cells called T cells that were predisposed to cause allergic reactions to some foods.”

The research used well-documented food allergy information collected by the Barwon Infant Study (BIS), a collaboration between

Barwon Health, Deakin University and the Murdoch Childrens Research Institute.

“There has been a threefold increase in hospital presentations due to food allergy over recent decades, and most of this increase has been among children under 5 years of age,” said co-author A/Prof Peter Vuillermin, who leads the BIS. “In fact, up to one in every ten babies in Melbourne develop food allergy during the first year of life.

“We don’t know why the increase in food allergy has occurred. The important thing about this study is that we’ve shown the immune systems of babies who develop food allergy are in a sense ‘primed’ for allergic disease by the time they are born.”

Harrison said that the research team would try to identify why these babies have hyperactive immune cells. “Are the immune cells inherently activated because of the baby’s genes or do they become activated at the time of birth or earlier in pregnancy, and how?” he asked.

“This study really emphasises how critical it is to look at pregnancy and early life to really understand why chronic immune and inflammatory disorders such as allergies develop in childhood and later.”

Nullarbor's Ancient Forests Uncovered

Rather than being the treeless, limestone expanse that the Nullarbor Plain is today, dating of fossilised pollen has revealed that five million years ago it received up to four times as much rain as it gets now and was an expanse of gum and eucalyptus trees, banksias and other flowering plants that are now confined to Australia's east coast.

The finding, published in *PNAS* (tinyurl.com/jcu7hyv), sheds new light on the environmental history of the Nullarbor, a former seabed that was lifted above the sea 14 million years ago.

"The Nullarbor region had a relatively dry climate until five million years ago, but then the vegetation suddenly changed," said Dr Kale Sniderman of The University of Melbourne. "In just 100,000 years it became a forest of gums and banksias, which suggests a rainfall of two or up to four times higher than today."

The Nullarbor Plain covers 200,000 km² bordering the Great Australian Bight between South Australia and Western Australia. It receives an average of 250 mm of rain each year, but before five million years ago the annual rainfall was approximately 480 mm and 3.5–5 million years ago it rose to an estimated 1220 mm.

Investigating the climate history of Australia's desert regions is traditionally difficult for scientists given the scarcity of fossils and the difficulty in accurately dating them.

The researchers dated speleothems – stalagmites, stalactites and flowstones deposited in caves – and then dissolved them to examine any ancient pollen trapped within.

"Most didn't contain any pollen, which isn't surprising since many speleothems grew in caves that had no openings to the surface," Sniderman said. "But some did contain fossil pollen, which revealed the nature of the vegetation growing at those times. Through that we've been able to develop a new understanding of the history of the Nullarbor's climate."



The Aliens Are Already Extinct

Life on other planets would likely be brief and become extinct very quickly, according to astrobiologists from The Australian National University who argue that new life would commonly die out due to runaway heating or cooling on their fledgling planets.

"The universe is probably filled with habitable planets, so many scientists think it should be teeming with aliens," said Dr Aditya Chopra, who is lead author of the research published in *Astrobiology* (tinyurl.com/jrmvsk2).

"Early life is fragile, so we believe it rarely evolves quickly enough to survive," he said. "Most early planetary environments are unstable. To produce a habitable planet, life forms need to regulate greenhouse gases, such as water and carbon dioxide, to keep surface temperatures stable."

About four billion years ago Earth, Venus and Mars may have all been habitable. However, a billion years or so after their formation, Venus turned into a hothouse and Mars froze into an icebox.

Any early microbial life on Venus and Mars failed to stabilise

the rapidly changing environment, said co-author A/Prof Charley Lineweaver. "Life on Earth probably played a leading role in stabilising the planet's climate," he said.

Chopra said their theory solved a puzzle. "The mystery of why we haven't yet found signs of aliens may have less to do with the likelihood of the origin of life or intelligence and have more to do with the rarity of the rapid emergence of biological regulation of feedback cycles on planetary surfaces," he said.

While wet, rocky planets with the ingredients and energy sources required for life seem to be ubiquitous, no signs of surviving extra-terrestrial life have been found. A plausible explanation is near-universal early extinction, which the scientists have named the Gaian Bottleneck.

"One intriguing prediction of the Gaian Bottleneck model is that the vast majority of fossils in the universe will be from extinct microbial life, not from multicellular species such as dinosaurs or humanoids that take billions of years to evolve," Lineweaver said.



Unhappiness Has No Effect on Mortality

A study of a million women in the UK has concluded that the widespread belief that unhappiness and stress directly cause ill health comes from studies that confused cause and effect.

Life-threatening poor health can cause unhappiness, and for this reason unhappiness is associated with increased mortality. In addition, smokers tend to be unhappier than non-smokers. However, after taking into account previous ill health, smoking and other lifestyle and socio-economic factors, the study found that unhappiness itself was no longer associated with increased mortality.

Lead author Dr Bette Liu, now at the University of NSW, said: "Illness makes you unhappy, but unhappiness itself doesn't make you ill. We found no direct effect of unhappiness or stress on mortality, even in a 10-year study of a million women."

The investigation, published in *The Lancet* (tinyurl.com/opuf7ez), was conducted within the UK Million Women Study. Three years after joining this study, women were sent a questionnaire asking them to self-rate their health, happiness, stress, feelings of control, and whether they felt relaxed. Five out of six of the women said they were generally happy, but one in six said they were generally unhappy.

As in other studies, unhappiness was associated with deprivation, smoking, lack of exercise, and not living with a partner. The strongest associations, however, were that the women who were already in poor health tended to say that they were unhappy, stressed, not in control, and not relaxed.

The main analyses included 700,000 women of average age 59 years, and over the next 10 years these women were followed by electronic record for mortality, during which time 30,000 of the women died.

After allowing for any differences already present in health and lifestyle, the overall death rate among those who were unhappy was the same as the death rate among those who were generally happy. The study is so large that it rules out unhappiness being a direct cause of any material increase in overall mortality in women.

This was true for overall mortality, for cancer mortality and for heart disease mortality, and it was true for stress as well as for unhappiness.



The Scent of a Queen Quells an Uprising by Her Subjects

Queen bees and ants emit a chemical that alters the DNA of their daughters and ensures they remain sterile and industrious workers.

"When deprived of the pheromone that queens emit, worker bees and ants become more self-centred and lazy, and they begin to lay eggs," said Dr Luke Holman of The Australian National University. "Amazingly, it looks like the queen pheromone works by chemically altering workers' genes."

Queen bees and ants can have hundreds of thousands of offspring and live for many years, while workers are short-lived and mostly sterile even though they have the same DNA as the queen.

Recent research suggests that methylation of a baby bee or ant's DNA helps to determine whether it develops into a queen or a worker.

Holman and co-workers from the University of Helsinki found evidence that workers exposed to the queen bee's pheromones tag their DNA with methylation differently, and believe that this might suppress any queenly characteristics in the workers.

While the queen pheromone of honeybees seemed to lower methylation, the queen pheromone of ants seemed to increase it, suggesting that methylation works differently in bees and ants.

"Bees and ants evolved their two-tier societies independently," Holman explains. "It would be confusing but cool if they had evolved different means to the same end."

The research has been published in *Biology Letters* (tinyurl.com/gp5jghj). Holman will be studying Australian bees next, which evolved sociality independently from the European species in this study. "It brings us one step closer to understanding how these animals evolved their amazing cooperative behaviour, which in many ways is a step beyond human evolution," he said.

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Moa Diet Fits the Bill

Australian and New Zealand researchers have discovered that the nine species of moa that roamed New Zealand until the 15th century were able to co-exist because differences in the structure and strength of each species' bills influenced or dictated their diet.

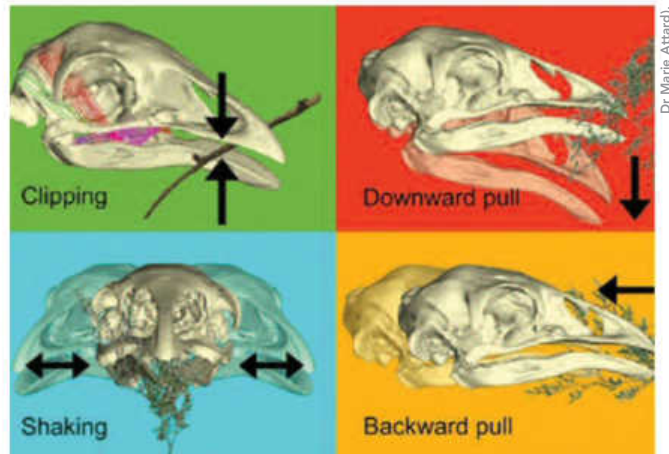
The moa were herbivores, and were some of the largest birds to have ever existed. The largest species, the South Island Giant moa, weighed up to 240 kg while the smallest, the upland moa, was the size of a sheep. Until now scientists had thought that the huge differences in size between the species determined their foraging behaviour as well as what, when and where they ate.

Prof Paul Scofield of Canterbury Museum says the team took the most complete skulls of each species and scanned them using medical CT scanners. "We then produced highly accurate 3D models of each. This wasn't a simple job as we didn't have a single skull that was perfect, so we used sophisticated digital cloning techniques to digitally reconstruct accurate osteological models for each species," he said.

Using medical MRI scans of mummified remains, the researchers digitally reconstructed the muscles of each species. Software used by civil engineers after the Canterbury earthquakes to identify weak or unsound buildings was then employed to test the strength and structure of each species' skull.

These were compared with each other and to two living relatives, the emu and cassowary. The models simulated the response of the skull to different biting and feeding behaviours, such as clipping twigs and pulling, twisting or bowing head motions to remove foliage.

Lead author Dr Marie Attard of the University of New England says that the skull mechanics of the moa were surprisingly diverse. "The little bush moa had a relatively short, sharp-edged bill and was



Three-dimensional computer models simulated the response of the skull to different biting and feeding behaviours.

superior among moa at cutting twigs and branches, supporting the proposition that they primarily fed on fibrous material from trees and shrubs.

"At the opposite extreme, the coastal moa had a relatively weak skull compared to all other species, which may have forced them to travel further than other moas in search of suitable food, such as soft fruit and leaves."

"Little has been known about how New Zealand's ecosystem evolved, largely because we know so little about how moa lived and co-existed," says A/Prof Stephen Wroe of the University of New England. "This new research advances our understanding about the feeding behaviours of the moa species and their impact on New Zealand's unique and distinctive flora."

The findings have been published in *Proceedings of the Royal Society B* (tinyurl.com/hw8wxt7).

Spinifex Makes Condoms Thinner and Stronger

Nanocellulose extracted from spinifex grass could make condoms as thin as a human hair without any loss in strength. "The great thing about our nanocellulose is that it's a flexible nano-additive, so we can make a stronger and thinner membrane that is supple and flexible," said Prof Darren Martin of the Australian Institute for Bioengineering and Nanotechnology (AIBN) at The University of Queensland.

"We tested our latex formulation on a commercial dipping line in the United States and conducted a burst test that inflates condoms and measures the volume and pressure, and on average got a performance increase of 20% in pressure and 40% in volume compared to the commercial latex control sample," he said.

"With a little more refinement, we think we can engineer a latex condom that's about 30% thinner, and will still pass all standards, and with more process optimisation work we will be able to make devices even thinner than this. Late last year we were able to get down to about 45 microns on our very first commercial dipping run, which is around the width of the hair on your head."

Martin said the benefits of the nanocellulose technology would interest latex manufacturers across the multi-billion-dollar global market. "Rather than looking at increasing the strength, companies would be looking to market the thinnest, most satisfying prophylactic possible," he said. "Likewise, it would also be possible to

produce latex gloves that are just as strong but thinner, giving a more sensitive feel and less hand fatigue to users such as surgeons.

"Because you would also use less latex, your material cost in production would potentially drop as well, making it even more attractive to manufacturers."

Martin said spinifex had long been used as an effective adhesive by indigenous communities in Australia. "Spinifex resins have been used traditionally for attaching spear heads to their wooden shafts," he said.

The University and the Dugalunji Aboriginal Corporation have signed an agreement to recognise local Aboriginal traditional owners' knowledge about spinifex and to ensure that they will have ongoing equity and involvement in the commercialisation of the nanocellulose technology.

Dr Nasim Amiralian of AIBN said the nanocellulose could be converted from spinifex using an efficient chemistry method. "You would firstly hedge the grass, and then it would be chopped up and pulped with sodium hydroxide - and at that stage it just looks like paper pulp," she said. "Then you hit it with mechanical energy to force it through a very small hole under high pressure to peel the nanofibres apart from the pulp, into nanocellulose happily suspended in water and ready to add to things like water-based rubber latex."



A southern hairy-nosed wombat on its burrow in the Murraylands.

Radar Uncovers Wombat Warrens

Very little is known about the burrowing habits of the southern hairy-nosed wombat, but now researchers from the University of Adelaide have used ground-penetrating radar to reveal the inner workings of their warrens.

“A major problem we are grappling with is understanding just how many wombats

there are and whether their numbers are increasing or decreasing,” said PhD candidate Michael Swinbourne.

“At the moment we use satellite imagery to count the warrens and then use that information to estimate the numbers of wombats living inside. This method isn’t

perfect because we don’t know much about how wombats share their warrens.”

Ground-penetrating radar allowed Swinbourne to map warrens built underneath thick layers of hard limestone – which occurs throughout much of the wombat’s range. He found that these differ substantially to soil warrens, with an extensive series of tunnels and chambers rather than simply a discrete tunnel underground.

“These findings have important implications for how we estimate the numbers of wombats, and also how we think about the social structure of a wombat colony. They might be more social than we previously thought,” Swinbourne says.

Wombats are considered an agricultural pest because their burrowing activity can cause damage to farm infrastructure and equipment as well as crops. Lessening the southern hairy-nosed wombat’s impact on agriculture on one hand, while conserving it on the other, continues to be a significant challenge for conservationists.

The research has been published in *Wildlife Research* (tinyurl.com/jt9qrfo).

Climate Change Makes Chicks Hatch Early

A study led by Macquarie University researchers has found that climate change is affecting how quickly bird eggs develop and hatch.

The study, published in *Royal Society Open Science* (tinyurl.com/zb9xtqo), found that hotter weather caused zebra finch eggs to start developing even before the parents had a chance to incubate them themselves.

“Typically, zebra finches will lay one egg a day for about 5 days, and will only start to incubate their eggs on the day that the last egg is laid,” explained Prof Simon Griffith, lead author of the study. “This way, all the eggs incubate and hatch at the same time in the nest, making it easier for the parents to feed and look after the chicks evenly.”

However, climate change is leading to more frequent heat waves when the birds breed, making them vulnerable.

“In the summer, we found that nests can get very hot, with recorded temperatures of up to 50°C. These birds usually like to incubate their eggs in temperatures between 36–40°C, and there is evidence suggesting that prolonged temperatures of over 40.5°C can be lethal to the developing chick embryos.

“If global temperatures were to increase, it could play havoc with the family dynamic of these birds, creating situations where a single nest contains chicks of different ages, and even causing some embryos to die if the temperatures remain too hot for a long period,” Griffith said.

The researchers point out that the warmer conditions may have



Credit: Chris Stacey, Macquarie University

both benefits and costs to the parents of the eggs. While the higher temperatures mean they might save time and energy on incubating the eggs themselves, they may also lose some of their younger and less developed chicks because they don’t preferentially feed the smallest chicks. Whether these birds can quickly adapt to the challenges of a changing climate remains to be seen.

“Future work will need to look at whether these birds, and other birds in general, are capable of adjusting to the alterations caused by climate change, particularly in the face of increasing average global temperatures and incidences of heat waves,” Griffith concluded.



tankist276/Adobe

Acupuncture Evidence Misses the Point

Traditional Chinese acupuncture treatments are no better than fake acupuncture for treating menopause symptoms, according to research conducted at The University of Melbourne.

Surprisingly, however, both real and sham treatments tested produced a 40% improvement in the severity and frequency of hot flushes at the end of 8 weeks of treatment, and the benefits remained 6 months after treatment.

The study, published in the *Annals of Internal Medicine* (tinyurl.com/hf73rgx), examined 327 Australian women aged over 40 who had at least seven moderate hot flushes per day. Half of the group had ten sessions of standard Chinese medicine acupuncture, while the other half received “sham” acupuncture using blunt-tipped needles that didn’t penetrate the skin.

Lead author of the study, Dr Carolyn Ee, said that plausible explanations for the

improvement in both groups included the placebo effect, attending a clinic to talk about symptoms, and spontaneous improvement of hot flushes over time.

“This was a large and rigorous study and we are confident there is no additional benefit from inserting needles compared with stimulation from pressuring the blunt needles without skin penetration for hot flushes,” Ee said. “If women want to consider having acupuncture for hot flushes, they should know that although previous studies show it is better than doing nothing, our study demonstrates that needling does not appear to make a difference.”

Women with breast cancer or who have had both ovaries removed were not included in the study. “These women suffer hot flushes that are more severe and often earlier in life, so we think they warrant specific research because breast cancer survivors can’t take hormone replacement therapy,” Ee explained.

She stressed that while acupuncture is a relatively safe treatment, women should also discuss other treatment options for their hot flushes with their doctor.

EMBRYONIC EDITING SPEEDS UP GENE STUDIES

The Children’s Medical Research Institute has developed a method to create mouse embryos from stem cells without needing live mutant mice. The method will make the generation of mutant lines in tissue engineering and organ generation studies 6 months faster.

The research, published in *Differentiation* (tinyurl.com/j3lce79), uses CRISPR-Cas9 genome editing technology to modify particular genes in mouse embryonic stem (ES) cells. The embryos are then allowed to develop in a mouse, and then epiblast cells are collected for the production of stem cells. The epiblast cells can be used to model embryonic development or be differentiated into a particular cell type for further study.

While conventional mouse ES cells are very different from reprogrammed human stem cells, the mouse epiblast cells are a very close parallel to the human system. They are considered useful for modelling inherited diseases through genome editing and the bioengineering of tissues and mini-organs.

The CMRI believes that these mouse stem cells could lead to better cell-based gene therapy and other treatments for human diseases, and is now offering genome editing of ES cells as a service to researchers.

New Tasmanian Devil Facial Cancer

Routine field research has identified a second transmissible cancer in Tasmanian devils that is very similar to Devil Facial Tumour Disease (DFTD). The new cancer has similarities to DFTD as it causes tumours, primarily on the face or inside the mouth, and is probably also spread between devils by biting.

Investigations into a possible second cancer began when researchers at the University of Tasmania’s Menzies Institute for Medical Research noticed cancer cells with features that weren’t typical of DFTD. Laboratory studies indicated that the case was a second, and therefore new, type of devil facial cancer.

Eight cases have been identified from the D’Entrecasteaux Channel area. “Fortunately this is similar to DFTD, and the procedures in place to deal with DFTD will be used to investigate this new cancer,” said Prof Greg Woods of the Menzies Institute. “Vaccine research will not be affected as the new cancer can be incorporated into the vaccine.”

When the different cancer cells were originally noticed, the Cytogenetics Department of the Royal Hobart Hospital undertook chromosome analysis and

established that the case was not DFTD.

When a second apparent case of DFTD from the same geographical area was discovered with the same chromosomal abnormalities it became likely that this was a new transmissible cancer.

Dr Elizabeth Murchison from the Department of Veterinary Medicine at the University of Cambridge, where genetic analysis of the new cancer took place, said that until now it had been thought that transmissible cancers arose extremely rarely in nature. “It makes us wonder whether transmissible cancers may not be as rare in nature as we previously thought. Alternatively, perhaps Tasmanian devils are particularly vulnerable to the emergence of transmissible cancers.”

Because there are now two types of devil facial cancers, the original transmissible cancer (first identified at the Mt William National Park) will be referred to as DFT1 and the second transmissible cancer (first identified in the Channel area) will be referred to as DFT2. Collectively they will be known as DFTD.

The research was published in *PNAS* (tinyurl.com/jmar2u7).



Male Bees Protect Females from STDs

The seminal fluid of male bees kills the sexually transmitted fungus *Nosema apis*, protecting queen bees from sexual transmission of the parasite.

Prof Boris Baer of The University of Western Australia's Centre for Integrative Bee Research said that the study, published in *Proceedings of the Royal Society B* (tinyurl.com/htcx7aa), found that male honey bee semen produced protein molecules that cause the *Nosema apis* fungus spores to germinate prematurely, killing them because they cannot survive outside of their hosts' cells. Another smaller molecule in the bee's semen could quickly kill the fungus spores directly.

"We also found that these immune molecules in the bee semen were specifically active against the fungus but had no effect on other microorganisms," Baer said. "This finding was surprising, because insect immune systems are often believed to be primitive and not very complex or specific."

Baer said the spread of parasites and pathogens globally are contributing to the alarming loss of millions of bees every year. "This is problematic, given our dependence on honey bees, as they pollinate more than 80 crops of agricultural interest or about a third of what we eat," he said.

"However this new finding, which confirms honey bees are remarkably capable of defending themselves against parasites, will provide exciting new ways to breed bees that cope with diseases by themselves. Suppressing parasites with chemicals has become a major issue because of contaminations of honey with residuals, as well as bee parasites having become more resistant against available treatments."

Solar Cells Ditch Doping

Scientists have developed a new silicon solar cell that promises cheaper manufacturing processes and better power output.

The research, published in *Nature Energy* (tinyurl.com/h88gvv6), did away with the chemical doping that conventional silicon cells rely on and instead used pure silicon sandwiched between thin films of different materials.

"For a lot of people this will broaden their idea of how silicon solar cells can be made," said lead author James Bullock, a PhD student at the Australian National University who conducted the study while on placement at UC Berkeley.

"These cells can be made using a very simple low-temperature fabrication procedure, so they have the potential for cheaper processing whilst still having high efficiencies."

The team's best solar cell so far has achieved nearly 20% efficiency, which is better than the industry average, said co-author Prof Andres Cuevas of ANU. "There is nothing to say we can't get to the world record efficiencies, over 25%, using this approach," he said.

Instead of using doping impurities within the silicon structure to control the electronic properties, the team sandwiched a silicon wafer between layers of lithium fluoride and molybdenum oxide.

Lithium fluoride has a low binding energy of electrons while molybdenum oxide's binding energy is very high. The difference means that when sunlight hits the silicon and creates an electron-hole pair, the electron is drawn to the lithium fluoride while the hole goes the opposite way, which creates an electric current.

The new design promises a lower energy footprint for solar cells because they can be manufactured below 200°C. Conventional doped cells must be made above 800°C. The cells also do not require the often-toxic chemicals used to dope conventional materials.

"This device is the result of a completely new understanding of the physics of solar cells," said Prof Cuevas. "All those wonderful materials were sitting there, some of them already in our lab cabinets, but we had not realised how useful they can be."

Light-Activated Cancer Therapy Isn't Just Skin Deep

Nanoparticles used in combination with X-rays can be used to kill cancer cells deep within the body, according to research published in *Scientific Reports* (tinyurl.com/h6hjggg).

The research is based on the successful quantification of singlet oxygen, a highly reactive form of oxygen that has been used in photodynamic therapy to kill or inhibit the growth of cancer cells. "Photodynamic therapy is where light-sensitive compounds are placed near diseased cells, then activated by light, producing short-lived molecular by-products that can destroy or damage the cells being targeted," explains Prof Ewa Goldys of Macquarie University.

"In this case, X-rays were used to stimulate cerium fluoride (CeF₃) nanoparticles which had been placed near a group of cells. Singlet oxygen was produced as a by-product of the X-ray and CeF₃ interaction, which was then successfully measured.

"Singlet oxygen molecules are a far more reactive form of oxygen but they can only kill cancer cells if generated in sufficient quantity", said Goldys. "In our testing we established that therapeutic radiation dose X-rays produce enough singlet oxygen molecules to be effective in photodynamic therapy."

Goldys says photodynamic therapy has traditionally used near-infrared or visible light, but this has been unable to penetrate far into the body, limiting its use to cancer treatment on or near the surface of the skin. "We're looking to target cancer cells deeper in the body, hence the use of X-rays, which can really penetrate into deeper levels of tissue, and which are already used in medical diagnosis and therapy. The beauty of this type of treatment is that it uses different biological pathways to kill cells as compared to chemotherapy, radiotherapy and other current cancer practices."

Different nanoparticles will next be tested for their effectiveness in producing singlet oxygen.

Motorboat Noise Helps Marine Predators

An international research team has found that noise from passing motorboats reduces the ability of coral reef fish to flee from predators. As a consequence they are captured more easily and their survival chances are halved.

Prof Mark McCormick of the ARC Centre of Excellence for Coral Reef Studies at James Cook University said that the study, published in *Nature Communications* (tinyurl.com/gsjsges), “shows that juvenile fish become distracted and stressed when exposed to motorboat noise, and predators capitalise on their indecision”.

“We found that when real boats were motoring near to young damselfish in open water, they became stressed and were six times less likely to startle to simulated predator attacks compared to fish tested without boats nearby,” said Dr Stephen Simpson of the University of Exeter, who led the study.

The team of scientists combined laboratory and field experiments, using playbacks and real boat noise, to test the impact of motorboat noise on the survival of young ambon damselfish during encounters with their natural predator the dusky dottyback.

The team is optimistic about the possibilities for management of noise and its potential impact. “Unlike many pollutants, we can more easily control noise,” McCormick said. “We can choose when and where we make it, and with new technologies we can make less noise. For example, we could create marine-quiet zones or buffer zones, and avoid known sensitive areas or times of year when juveniles are abundant.”



A predatory dottyback eyes off a juvenile ambon damselfish.

Credit: Christopher Mirbach

Managing local environmental stressors such as noise is an essential first step in protecting the marine environment. “You might argue that climate change is a bigger threat to reef life, but if we can reduce the effect of local noise pollution we build greater resilience in reef communities to looming threats such as global warming and ocean acidification,” said Dr Mark Meekan of the Australian Institute of Marine Science.

Marine Parks Don't Protect Diversity

Most of the evolutionary diversity of corals and fish is not currently supported by the world's network of marine protected areas, prompting marine scientists to call for a rethink of how marine protected areas are planned and coordinated.

Researchers from the Australian Research Council Centre of Excellence for Coral Reef Studies (Coral CoE) at James Cook University analysed the extent to which the evolutionary histories of corals and fishes are protected, rather than looking at individual species. “Our interest was in evolutionary branches of the tree of life, rather than the traditional focus on rare, threatened or endemic species,” said Prof David Bellwood of the Coral CoE. “In particular we were interested in the longer branches, which represent the greater proportion of evolutionary history.

“When we looked at tropical Marine Protected Areas from that perspective, we found that protection of corals and fishes falls significantly short of the minimum conservation target of protecting 10% of their geographic ranges. Just one-sixteenth of hard coral species are afforded that minimum level of protection, and for fishes – the wrasses – less than a quarter reach minimum protection levels.”

Bellwood said that while it was still useful to focus on the conservation of rare, threatened and endemic species, planning protected areas around evolutionary history helped to provide a deeper perspective. “It is not just species that need protection but the genetic



Less than one-quarter of wrasse species receive minimum protection levels. Credit: João Paulo Krajewski

history that they contain. In a changing world this evolutionary diversity is likely to be increasingly important as reefs respond to new challenges.”

The researchers found that the shortfall in protection for corals was greatest in the Atlantic and the Eastern Pacific. For fishes, the highest concentrations of poor protection are in the Western Indian Ocean and the Central Pacific.

“Even though our estimates are highly conservative, the inescapable conclusion is that most evolutionary branches of the tree of life on coral reefs are inadequately protected by the current system of Marine Protected Areas,” Bellwood said.

The research was published in *Nature Communications* (tinyurl.com/jhn4ve9).

Sugar Cravings

DANIEL HWANG

We all differ in our sensitivity to natural and artificial sweeteners, but how much of this is genetic and how much due to the influences of our sugar-fuelled culture?

While some people love the taste of Tim Tam biscuits, others find them too sweet. Our research suggests that our genes influence these individual differences in the perception of sweetness.

Taste has a significant impact on our life. It contributes to our enjoyment by stimulating a desire to eat, and therefore plays an essential role in our selection of food and nutrients. It also acts as a natural defence against food poisoning by alerting us to spoiled foods and potential toxic compounds.

We can perceive five basic taste qualities – sweetness, saltiness, sourness, bitterness and umami (savoury) – with sweetness generally considered pleasant by most people across all ages. Sweetness signals the presence of carbohydrates, the main energy source for the human body, and hence is essential for feeding, metabolism and early development.

“One in every ten Australian children is unable to taste food properly...”

However, not everyone has a normally functioning sense of taste. One in every ten Australian children is unable to taste food properly, and has difficulty distinguishing one taste quality from another. In the USA more than 200,000 people each year seek medical advice for taste or smell problems, which include changes in taste quality, intensity or hallucinations. The exact causes behind this are not fully understood, but may result from normal ageing, head injuries or a side-effect of chemotherapy and radiotherapy.

These taste problems can have a severe impact on health and life quality. For instance, the primary cause of morbidity in 20% of cancer patients is malnutrition rather than malignancy. Cancer treatments can alter sensory perception, with food becoming tasteless or in some cases possessing a metallic

taste. This leads to a further decrease in dietary intake and the development of food aversion.

Taste perception also varies widely between healthy individuals – think about how many teaspoons of sugar you and others add to tea or coffee – with such differences affecting health and well-being. For example, people with weaker taste sensitivity are more susceptible to certain diseases, such as obesity, diabetes and hypertension, because they need to consume more salt, sugar or fat to have the same taste sensation.

What are the causes of the differences in sweet taste? When we eat, food chemicals are detected by taste receptors in taste buds on the tongue. A signal is sent through taste nerves to the brain, where the taste is identified and a sensation of pleasantness or aversion is elicited.

In 1990, researchers found that heightened sweet taste sensations could be due to the increased number of taste buds on the tongue. About 10 years later it was proposed that differences in signal processing in the central nervous system also cause differences in taste perception. More recently, genetic studies have revealed that sweetness perception is related to variations in sweet taste genes. However, the magnitude of the genetic influence has not been resolved.

Is our sensitivity to sweetness simply due to biological inheritance? Or is it acquired through environmental exposure, such as diet, education, socioeconomic status or culture? The aim of our study was to estimate the strength of genetic and environmental effects on our sensitivity to sweetness.

Sugar is the main source of sweetness, and is used to enhance the palatability of food and drink. In the past decade, the use of aspartame, saccharine and many other artificial sweeteners as sugar substitutes has significantly increased because of their low or non-caloric characteristics. Interestingly, mice use different sweet taste systems to detect sugars and sugar substitutes. Whether the same systems exist in humans is unclear.

We studied the sweet tastes of two sugars (glucose and fructose) and two sugar substitutes (aspartame and neohesperidine dihy-



Yurok Aleksandrovich

drochalcone). The two sugars are sources of sweetness in fruits, vegetables, honey and many other natural products. The two sugar substitutes are hundreds of times sweeter than sugars of the same concentration, and are widely used as food additives in sugar-free or non-caloric foods and drinks, such as sugar-free pudding, chewing gum and diet soft drinks and flavoured water.

The project was part of the Brisbane Adolescent Twin Study. Twins are very important for studying genetic effects because of their biological similarities and differences. Since identical twins share 100% of their genes while non-identical twins and siblings on average share only half of their genes, if identical twins have more similar sweet taste than non-identical twins it is evidence of the strength of genetic influence. Utilising this concept, we were able to estimate the extent to which sweet taste is exclusively attributable to differences in our genes.

In order to accurately estimate genetic effects, a large sample size is necessary. After more than 10 years of data collection, the study amassed a sample of 1901 participants, comprising 243 identical and 452 non-identical twin pairs and 511 non-twin

"We also found that individuals with a history of middle ear infection had a stronger sweet response."

individuals. This provided us with sufficient power to examine genetic influences on sweetness perception.

Twins and their siblings aged between 12 and 26 years old were asked to taste solutions of the four sweeteners and then rank them on a scale ranging from no sweet sensation to the strongest imaginable sweetness. Our results revealed that around 30% of sweetness is due to genetics, regardless of the sweetness source tested (sugar or sugar substitute). Since our sweet taste is partially encoded in genes that are passed from our parents and ancestors, it would not be surprising to see family members possess similar preferences towards sweet foods.

In addition, the study results showed that the sweet responses to these four sweeteners were highly correlated. For example, if you perceive glucose to be intensively sweet, then you are also



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"Intriguingly, your favourite childhood lollies or sweets may become less tasty or even unpleasant as you age."

likely to find fructose, aspartame and neohesperidine dihydrochalcone highly sweet.

The results also suggested that there is a single set of genes responsible for the perception of all four sweeteners. This suggests that, unlike mice, humans use the same system to detect sweetness in both sugars and sugar substitutes.

Intriguingly, your favourite childhood lollies or sweets may become less tasty or even unpleasant as you age. Most people may notice their preference for sweet foods changes with time. Our study showed that human perception of sweetness decreased by 2–5% per year. This suggests that the sweet taste system changes from childhood to adulthood, and may explain why children are more sensitive to sweetness than adults. This lessening of taste perception is also found for bitterness, and applies to the majority of the population.

We also found that individuals with a history of middle ear infection had a stronger sweet response. These results were unexpected, as middle ear infections are generally thought to lower taste sensation by damaging the taste nerve that runs from the tongue to the brain. It has been proposed that middle ear infections can lead to an increase in the number of taste buds in compensation for the loss of taste sensation. Individ-

uals recovering from middle ear infection would therefore have more taste buds than they had prior to the infection, and this in turn may result in a stronger taste response.

If sweet taste is indeed influenced by genetics, does this mean that people with weaker sweet perception are likely to keep adding more sugar to their diet? If so, this could lead to a serious public health problem in which obese individuals become even more obese.

Fortunately, this is not necessarily the case. Our study also suggested that part of the sweetness is related to environmental factors. As such, it is still possible for people to change their dietary habits through education or dietary management.

Our next steps are to identify key genomic regions responsible for individual differences in sweetness, with the hope of understanding the underlying molecular mechanisms of human sweet taste perception. The research may provide new strategies to reduce dietary sugar intake and provide clues to solving taste disorders, which can have a significant impact on eating patterns and nutritional status and consequently are a risk factor for heart disease, diabetes and stroke.

Daniel Hwang is a PhD student in the Genetic Epidemiology Group at the QIMR Berghofer Medical Research Institute.



Should Australia Allow Mitochondrial Donation?

AINSLEY NEWSON & STEPHEN WILKINSON

Is there any ethical reason why legislation should prevent the use of donor mitochondria in cases where children are likely to inherit mitochondrial disease from their mothers?

The transfer of a donor's healthy mitochondria into a woman's egg or early embryo aims to prevent a child from inheriting mitochondrial disease from its mother. In February 2015 the United Kingdom became the first country to allow the technique, and last month the US Institute of Medicine also determined that mitochondrial donation is acceptable in some circumstances.

Current laws and regulations in Australia are unlikely to allow this treatment to be used clinically so that children can be born with donor mitochondria. However, in all states and territories (except Western Australia), undertaking embryo research into at least some methods of mitochondrial donation may be possible under an appropriate licence.

So far, no such licences have been granted. There are also no plans to review these laws, with the most recent review in 2011 rejecting any change to allow mitochondrial donation.

Should Australia now follow these overseas developments?

Mitochondrial Disease

Mitochondria are organelles within our cells that are responsible for energy generation. It's thought that they originated in bacteria but now exist in our cells in a symbiotic relationship.

Mitochondrial disease occurs when these mitochondria don't work properly. These diseases take many forms but often they affect energy-intensive body parts such as the brain, liver or heart. Mitochondrial disease is debilitating, is often fatal, and at present there's no cure.

Many mitochondrial diseases are caused by problems in the DNA of the mitochondria themselves, which is separate from the DNA found in a cell's nucleus. Mitochondria are only passed on via the mother; a pattern known as matrilineal inheritance. This means that a man with mitochondrial disease will not pass it to his children. Whether a woman passes it to her children depends on the balance of healthy and mutated mitochondria in her egg cells.

Mitochondrial DNA is also prone to developing new mutations. This makes it hard to predict reliably whether and how someone will be affected by mitochondrial disease.

Mitochondrial replacement is proposed as a way of preventing disease from being passed from mother to child. One technique, maternal spindle transfer, removes the chromosomes from an egg cell with damaged mitochondria and inserts them into a donated egg that has healthy mitochondria. This egg is then fertilised and implanted in much the same way as standard in vitro fertilisation.

Another technique, pronuclear transfer, transplants the nuclei of a sperm and egg (together termed the “pronuclei”) from an embryo created by the parents to an early embryo created using the father’s sperm and a donated egg that has had its own pronuclei removed.

“... the main alternative for these families – having a child affected by mitochondrial disease – is so bad that a certain level of risk is justified”

Both techniques will result in an embryo that has nuclear DNA from the mother and father, and mitochondria from a donor. Any child created would be genetically linked, through mitochondrial DNA, to an egg donor as well as to his or her main genetic parents – hence the expression “three-parent IVF”.

“Three-Parent” IVF?

Should it matter that a child has three biological parents? The first thing to think about here is whether mitochondrial donors are really a “parent”. While the children created will be genetically linked to the donors, it’s far from clear that this link is sufficient to make them parents.

Only around 0.1% of our genes are contained in mitochondria (the other 99.9% is in the cell’s nuclei), so the donor only provides a tiny fraction of the child’s genetic material. That said, this DNA is important: it determines the difference between health and illness. It’s also present in thousands of copies per cell, while there are only two copies of each gene in the nucleus.

We can also ask whether there’s really anything bad about children having a biological link with three people. There are already lots of families that only exist because of the biological input of a third person, such as children created using traditional egg donation or through surrogacy. In the case of egg donation, for example, the child’s “social mother” becomes pregnant and gives birth to her child but she is not genetically related to her baby because the egg came from a donor.

Thus it’s not clear that “three parent IVF” (if that’s what mitochondrial donation is) would be all that different from practices that we already accept.

Genetic Modification

Another concern is that mitochondrial donation is a kind of genetic modification that will affect future generations. This has ethical relevance as it could permanently change the gene pool. Some people are concerned that this sort of genetic modification is too dangerous due to the unknown nature of its effects (e.g. the US Institute of Medicine recommends that this technique be used only to implant male embryos to avoid passing on donor mitochondria). Others object to it because they think it is wrong to “interfere” with human nature to this extent.

But against this, it could also be argued that mitochondrial replacement isn’t really modification. Donated mitochondria are naturally occurring (in the donor’s egg) and not engineered or manufactured.

There is also no change at the level of DNA; rather, it involves the substitution of one set of mitochondria for another. This means that we’re using genetic material that already occurs in nature, not adding anything new or artificial. According to this view, mitochondrial replacement is more like an organ transplant than like genetic engineering.

Furthermore, many different policy decisions have major effects on those yet to be born, such as decisions about the environment and climate change, or whether to go to war. Mitochondrial replacement is not unique in affecting the future and, given the small numbers involved – around one in 5000 people will develop serious mitochondrial disease – its effects may be quite limited compared with other things that we do.

The Ethics of Safety and Risk

In the UK, a high-level scientific review committee deemed mitochondrial donation safe enough to proceed to clinical use. However, this doesn’t guarantee that this treatment will be risk-free. Debates are ongoing in the scientific literature about what effects might occur as a result of mitochondrial transfer. Some worry that data from experiments in species such as mice and fruit flies, in which swapping mitochondria had untoward effects, have been overlooked. Others argue that these data are not transferable to humans or are being over-interpreted.

From an ethical perspective, the key issue is how we should decide on the acceptable level of risk for mitochondrial donation. Sometimes a precautionary approach can be taken, in which the use of a new technology is limited until serious risks are known to be minimised. However, this can lead to long delays. It is also important to keep in mind that the main alternative for these families – having a child affected by mitochondrial disease – is so bad that a certain level of risk is justified in order to prevent this suffering.

Is Mitochondrial Replacement Unnecessary?

Some have also argued that we shouldn't allow mitochondrial replacement because it's not needed. The argument here is that affected parents already have other options so there's no need to develop mitochondrial replacement. For example, Canadian bioethicist Françoise Baylis argues that:

women at risk of having children with mitochondrial disease can have their own children using much less risky alternatives. For example, they can make a baby the old fashioned way, have prenatal diagnosis and, if the fetus is affected, they can choose to have a termination of pregnancy. Alternatively, they can make an embryo using IVF and have preimplantation genetic diagnosis... They can have IVF and egg donation or embryo donation. They can choose to adopt a child. Using one or other of these options, women can become mothers without putting their future children in harm's way with the use of mitochondrial replacement technology.

While these are all potential options, prenatal diagnosis or preimplantation genetic diagnosis are not possible for many couples who are at risk of passing on mitochondrial disease. If a woman's eggs have mainly or only mutated mitochondria, then any child born from one of those eggs will have the same high level of mutation. No amount of selecting is going to change that.

And finding a suitable egg donor or adoptive child isn't easy. In 2013, only 406 babies were born from egg donation in Australia – a fraction of the 300,000 or so children born that year. Australian couples seeking egg donation also often travel overseas to find a donor, prompting the Australian Health Ethics Committee to propose legalising payment for egg donors here. Additionally, the most recent adoption statistics for Australia show that there were only 317 adoptions in 2013–14. Of these, only 12% of adoptions involved children under 12 months of age.

It is also apparent that – in common with many other families – couples at risk of passing on a mitochondrial condition attach value to the genetic link between parent and child and would very much like to have children who are both genetically “theirs” and free from mitochondrial disease.

A Right to Know?

Australian guidelines state that “persons conceived using ART procedures are entitled to know their genetic parents”. This raises the question of whether mitochondrial egg donors should be considered as “genetic parents” for these purposes. It also raises the question of whether children created as a result of mitochondrial donation should have a right to know who the egg donor was.

However, it might also be argued that mitochondrial donors aren't biological parents because their genetic contribution is so limited and that – unlike “regular” egg and sperm donors – children created via mitochondrial donation won't inherit their donors' most important personal characteristics, which pass via cell nuclei.

If donor information can be stored without imposing huge costs on clinics and without putting off too many donors, a case can be made for storing information about mitochondrial donors with a view to releasing this when the children created reach maturity. Those who don't want to access this information needn't do so, but some may have a strong desire to know more about their origins and may be frustrated or distressed if information is withheld.

Thus it may be best to err on the side of caution and to retain donor information for those who want it.

Moving Forward, Cautiously

It's too early to say whether mitochondrial replacement techniques can be developed that are sufficiently safe and effective for widespread clinical use. As with any new medical treatment, thorough evaluation and research is needed. There is, however, no conclusive ethical argument against proceeding with this research. In addition, given the importance to many people of having a child who is both genetically “theirs” and free from mitochondrial disease, there's a strong case for allowing it to proceed, provided that there's rigorous regulation and monitoring.

Ainsley Newson is Associate Professor of Bioethics at the University of Sydney. Stephen Wilkinson is Professor of Bioethics at Lancaster University, UK.




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An image of the centre of the Coma Cluster. Green dots show the distribution of thousands of faint dwarf galaxies, which do not include the recent discoveries of large, ultra-diffuse galaxies. In this crowded region of space, galaxies will frequently interact gravitationally with one another and the underlying dark matter of the cluster itself.

Credit: NASA/JPL-Caltech/GSFC/SDSS

Dark matter in the life of dead galaxies

CAMERON YOZIN

A recent discovery in the Coma Cluster highlights the important role of dark matter in transforming galaxies.

The billions of galaxies that make up the known universe come in a dazzling array of masses, shapes and colours. In the past few decades we've made incredible advances when it comes to observing these galaxies and better understanding how such diversity arose in the universe, yet our observations continue to surprise us.

To understand why galaxies look different, consider the fact that people, born in different parts of the world and going about their individual lives while interacting with different people, look different. Similarly, we find that the appearance of galaxies, ranging from the smallest with only a few thousand stars to the largest with more than a trillion times the mass of our Sun, are a product of the environment in which they form and the interactions they then have with other galaxies.

While people have some choice over the direction their lives take, the fate of galaxies is controlled by the all-permeating force of gravitational attraction. In many cases, this causes them to collide in spectacular fashion, leading to the formation of

yet more massive galaxies. In other cases, a galaxy may be drawn towards the combined gravity of many other galaxies lying in a single gravitationally-bound structure known as a galaxy cluster.

Transforming Galaxies

The Coma Cluster, which lies 300 million light years from us, is a relatively close and massive example of a cluster of thousands of galaxies that have been trapped in a cosmic dance for billions of years. Most of these galaxies could be described as “dead”: their elliptical shape and red colour implies that they have formed no new stars in a long time.

In contrast our home galaxy, the Milky Way, is a “living” spiral disk emitting a relatively blue colour thanks mostly to ongoing star formation. According to the prevailing theory of galaxy formation, our Milky Way more closely resembles the disk shape that most galaxies are thought to have been born with.

This disparity in colour and shape appears to be directly related to the different environments in which these galaxies

exist. Whereas the Milky Way has so far resided in a relatively low density region of the universe, on the outskirts of the Virgo Cluster, the Coma Cluster has a high density of galaxies, making it a dangerous place for galaxies wishing to retain a disk shape and continue to grow through the formation of new stars.

Close gravitational interactions between galaxies can “heat” or distort their disks so that they thicken to a more rounded shape or are destroyed entirely. At the same time, the cold hydrogen gas within a galaxy, required to fuel star formation, can be lost when the galaxy is drawn into a cluster. In much the same way as wind pressure pushes against your hand if it’s held outside a moving car, this cold gas is pushed out of the galaxy by hot dense gas lying inside the cluster.

These same methods of transforming galaxies have been observed among the roughly 50 known small galaxies that orbit our Milky Way. As these “dwarf” galaxies are close enough to us for detailed analysis of their stellar populations, we have discovered that they were “killed” almost as soon as the gravitational attraction of the Milky Way took hold of them as much as 10 billion years ago.

The singular exceptions are the blue, disk-shaped Magellanic Clouds. Visible as fuzzy patches of light on a clear night in the Southern Hemisphere, the Magellanic Clouds are believed to have only started to orbit the Milky Way in the past few billion years.

An Unexpected Discovery

The mechanics of galaxy transformation aren’t fully understood yet. For example, we don’t know exactly how long it takes galaxies of different masses to be affected by their respective environments.

While it was generally accepted that disk galaxies do not survive long in clusters, discoveries since late 2014 have not only contradicted this belief – they have revealed some of the most extreme disk-shaped galaxies ever found.

The story starts when a North American team, using an innovative new telescope comprised of camera lenses designed for wildlife photography, turned their gaze to the Coma Cluster. Originally they were looking for faint light in between galaxies as evidence of stars removed by gravitational interactions. Instead, they found galaxies so faint that earlier observations of the cluster made with higher resolution telescopes most likely looked straight through them!

Analysis of these new galaxies produced some startling results (Fig. 1). Some were as large in size as our Milky Way but with only 1% of their mass tied up in stars. With starlight spread so thinly throughout this new type of galaxy, they became known as “ultra-diffuse” galaxies. Their discovery motivated astronomers to revisit the archived observations of the Japan’s Subaru telescope, and they found that there could be thousands of these galaxies located throughout the Coma Cluster. Then, when another team used the same technique to look at Virgo, a near-neighbour of the Milky Way, they not only found more ultra-diffuse galaxies but galaxies that were even larger and even more diffuse.

No galaxies with such extreme properties had previously been detected, especially in a dense cluster environment. The closest type of galaxies with properties similar to the new ultra-diffuse galaxies are known as “low surface brightness” galaxies,

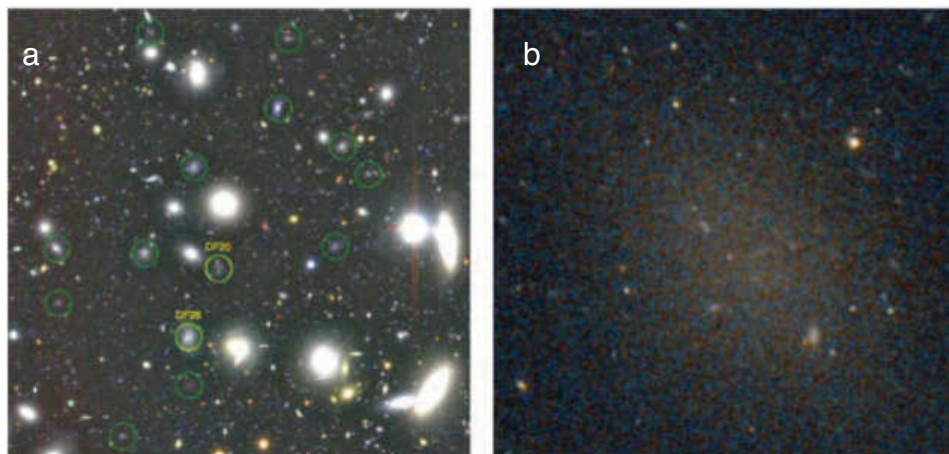


Figure 1. (a) Ultra-diffuse galaxies (circled) in the Coma Cluster. (b) A close-up view of the ultra-diffuse Dragonfly 44 galaxy, which is similar in size to our Milky Way although it has only about 1% of its stellar mass. Credit: Jin Koda/Pieter van Dokkum

but both galaxy formation theory and actual observations consistently show that these galaxies cannot exist in dense regions like clusters. In the case of the ultra-diffuse galaxies, their red colour and widespread distribution in both the low and high density regions of the Coma Cluster implies that they were gravitationally drawn into it and stopped forming stars as early as seven billion years ago, which is half the age of the universe.

The Role of Dark Matter

How do we explain these puzzling observations? Since these galaxies have only recently been discovered, astronomers have only limited data with which to find a solution. What we do know, however, is that dark matter must play an important role.

Dark matter is the elusive substance that makes up about 80% of all matter in the universe. It doesn’t interact with electromagnetic waves (light), and is therefore invisible to us.

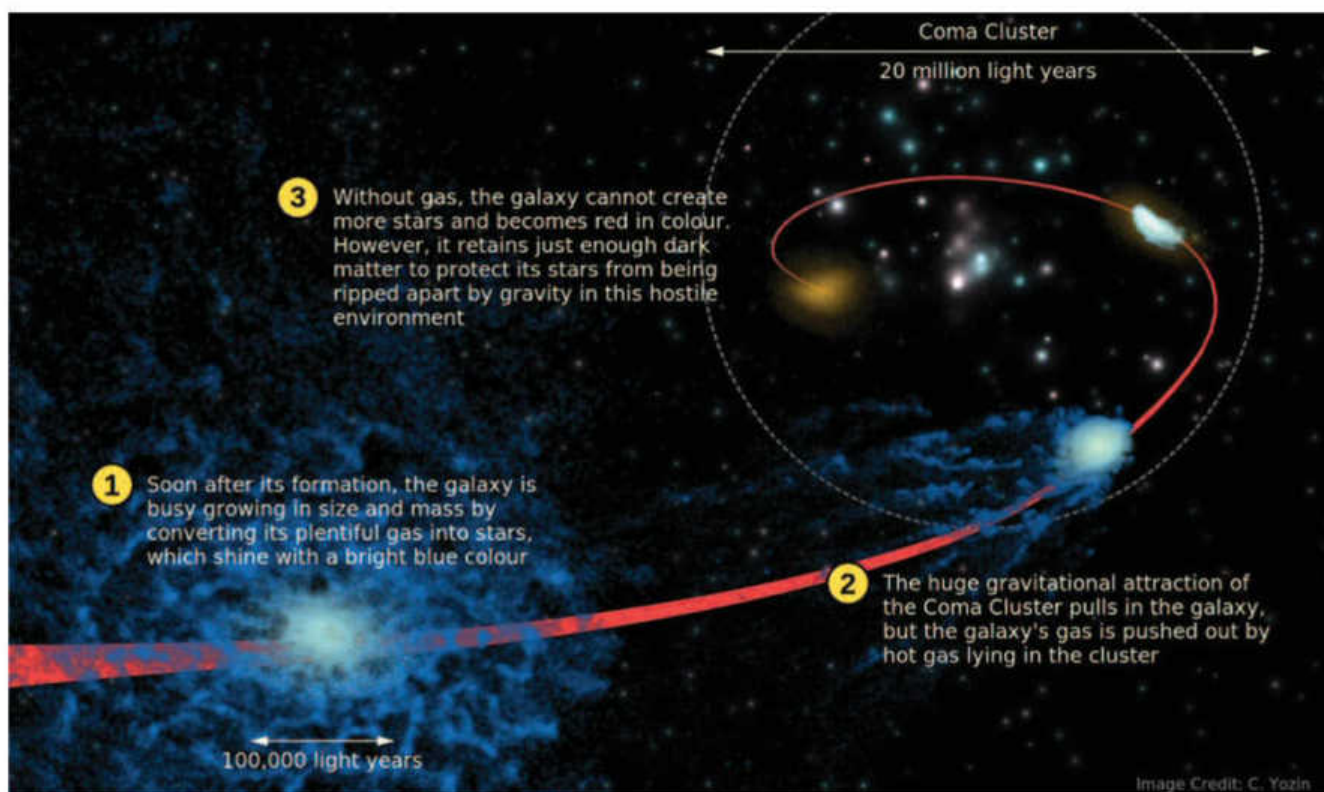


Figure 2. An artist's impression of how a galaxy can be transformed from a normal blue star-forming disk galaxy to an ultra-diffuse object when drawn into the Coma Cluster by its immense gravitational attraction. Credit: C Yozin, ICRAR

However, there is very strong evidence that it exists, starting with the discovery in the late 1970s that the speed of stars within many galaxies could not be possible if there was not some additional invisible mass binding them together.

Further evidence lies in the distortion of the path of light when it passes near massive objects, as predicted by Einstein's theory of general relativity, and observed directly in cases such as the Coma Cluster. In fact, it is by measuring this distortion that the total mass of the Coma Cluster can be found, revealing not only that it is 1000 trillion times as massive as our Sun, but that only about 10% of this mass is in a visible form such as stars or gas.

Just as gravitational interactions between galaxies in the Coma Cluster can transform them, so too can an interaction with the Coma Cluster's substantial dark matter. Most of this mass is concentrated at the centre of the cluster. Therefore, any ultra-diffuse galaxies close to this centre are most at risk of having their disk shape destroyed.

One method by which a galaxy can slow down the process of being destroyed by the gravity of another object is by being relatively massive itself. This makes it possible to perform a simple calculation to work out how much mass an ultra-diffuse galaxy requires to avoid being dramatically transformed through interaction with the dark matter in the Coma Cluster. The result: some of these galaxies must have had 100 to 1000 times as much mass tied up in dark matter than in stars when they fell

into the Coma Cluster.

But how can more than 99% of a galaxy's mass be dark matter if the average amount of dark matter in the universe is only 80%? In the case of the ultra-diffuse galaxies, the mass of non-dark matter material could be extremely low if cold hydrogen gas had been removed from the galaxies before they could form most of the stars they would have if the galaxies had not fallen into the Coma Cluster (Fig. 2).

Simulating the Death of Galaxies

This solution to the puzzle fits nicely, but we need to test the idea more rigorously to see if it works. Astronomy is unique among sciences insofar as it is almost impossible to do experiments with real galaxies, so the best option is to build a detailed model of a galaxy and its environment inside a supercomputer. By incorporating into our model all the physics and chemistry we believe play an important role in the evolution of the galaxy, we can simulate its evolution over billions of years and check its properties to see if they match those of the galaxies we see in our observations.

This method was applied to the case of ultra-diffuse galaxies to ask two key questions: can the hot gas of the Coma Cluster push out the cold gas of a galaxy that fell into it as early as seven billion years ago? And can a disk-shape satellite of Coma survive for this long if it contains 99% dark matter?

To answer both questions, we need to know the mass and

composition of the Coma Cluster in the past. Unfortunately, we have no time machine to go back in time to find this out, so instead we recall the fact that looking deeper into space is akin to looking back in time, given that the speed of light is finite.

So, if we can find real galaxy clusters in the distant past that resemble an earlier version of the Coma Cluster, we can base our ultra-diffuse galaxy cluster model on it. To work out what an earlier version of the Coma Cluster should look like, we refer to the results of recent super-computer simulations of the universe, which have shown in great detail how Coma-sized collections of galaxies have been assembled over cosmic time.

The next step is to build a model of a galaxy that, when put into our model of the Coma Cluster and allowed to evolve over billions of years, ultimately resembles the ultra-diffuse galaxies that we've observed. To do this, we refer to the theory of galaxy formation that explains how various properties of a primitive galaxy, such as its size and gas content, are correlated with its dark matter mass.

By running these simulations on supercomputers located at The University of Western Australia, we can successfully reproduce the theorised scenario for the formation of the ultra-diffuse galaxies and see that, despite such an immense amount of dark matter, these galaxies cannot survive indefinitely. The dark matter in the Coma Cluster continuously steals the dark matter and stars of the galaxies orbiting within it, gradually weakening their resistance and leading to their eventual demise.

The Next Step

Although these simulations were successful, our work in understanding this new type of galaxy has only just begun. By supporting the idea that a dark matter dominated galaxy can survive the chaotic environment of the Coma Cluster, future observations with state-of-the-art telescopes will be undertaken to find indirect evidence of this mysterious substance, using the individual motions of stars in the ultra-diffuse galaxies. We



The thin streaks of light surrounding the centre of this cluster, which lies four billion light years away, are the magnified and distorted images of background galaxies. By mapping these distortions, astronomers can work out the mass and distribution of the dark matter that causes them. Our simulations use this information to work out the strength of gravitational interactions that a galaxy will experience if it resides here. Credit: NASA/ESA/HST

can also establish how long these galaxies have resided in the cluster by measuring their velocity distribution.

These future discoveries will allow us to refine or revise our ideas about the origin of this unusual type of galaxy, leading to improved models that may answer some significant questions.

- Do these galaxies exist only in clusters?
- Did these galaxies fall into a smaller cluster first, before that cluster fell into the Coma Cluster?
- Have these galaxies actually fallen into the Coma Cluster only recently, to be observed shortly before their destruction commences?
- Did these galaxies stop forming stars through some other means, such as when their most massive stars exhaust their fuel and explode with enough energy to blow out all the cold hydrogen gas initially contained in the galaxy?

With such extreme properties, the exciting discovery of these ultra-diffuse galaxies will aid in our understanding of the extraordinary diversity in galaxies and the processes involved in their evolution.

Cameron Yozin is a research assistant at The University of Western Australia node of the International Centre for Radio Astronomy Research.

High Society

BILL ELLIS

GPS collars have revealed that koalas are more social than previously realised.

Koalas are mostly arboreal and nocturnal, so their social system has been difficult to study. The koala's mottled grey fur also makes it vanish among the canopy by day, so while we have been able to discover a lot about what they eat and where they live, how they interact has remained somewhat of a mystery – until recently.

We have been able to use smart phones and GPS-enabled radio collars to study how koalas communicate and move. And we've found that the females are much more socially interactive than the males.

Now we just need to figure out why. If we want to conserve their resources effectively we have to work out how they communicate, how they choose mates and why small populations have become extinct. If we don't know what the critical parts of their social structure are – or even if such things exist – then we are doomed to misunderstand their habitat requirements.

Of all the things koalas do – and they don't seem to do a lot – their distinctive bellow that rumbles through the forests each spring must be about the most interesting. The bellow is loud, long and like no other sound you hear, but its role in koala biology has only recently been properly studied. We now know that every bellow is an individual signature telling other koalas not only where another one is, but who and how big that koala is.

Koalas are most active at night when it cools down in Queensland, so they are at their busiest when the need for water to stay cool is at its lowest. Koalas don't sweat but they do pant, and since they get almost all of their water from the leaves they eat, water is a critical consideration for them.

Finding mates and avoiding adversaries in the middle of the night requires more than just good eyesight. Koalas have eyes similar to cats, with a vertical pupil that closes tightly by day but expands to allow good night vision.

Even so, misjudging the size of a competitor when high up in a tree can be costly for male koalas. Falls are common, and can result in debilitating injuries and even death, so koalas need more than the sight of a furry ball in an adjacent tree to decide whether to approach or avoid it.

Our group decided to investigate koala bellows. We established a suite of "listening stations" that consisted of a mobile phone attached to a large battery and solar panels. The phone turns itself on, records for a few minutes each hour and uploads the sounds to a server so we can listen to them almost in real time.

From my desk in Brisbane I can hear the koalas on St Bees Island, 20 km off the coast of Mackay, bellowing away as summer approaches. With the help of researchers from Queensland University of Technology and Sussex University in England, we began a set of experiments to decipher the bellows and interpret the associated koala behaviour we observed.

A key to this was to monitor every koala on our island study site using GPS and proximity logging radio collars. As well as letting us track the koalas by day, these collars recorded how far they moved every few hours, and also which other koalas they came into contact with.

Back in Brisbane, my colleague Ben Charlton recorded the bellows of captive koalas and analysed the spectrograph of each one. We also took the recorded bellows into the field and played them to koalas as well as re-recording them over distances to see how far the information travelled.

We first discovered that koalas tend to bellow very late at night. Although we had heard bellows around dawn and dusk, midnight to 4 am is when most of the bellowing activity occurs. On days when male koalas bellow more, female koalas move further, suggesting that the males were advertising and the females were going on excursions and selecting mates.

Each koala has a unique bellow, and other koalas are able to identify one another by their bellow. The bellow is an accurate indicator of the size of a koala. The koala has unusual vocal folds that it uses to create the bellow sound, and this sound is passed through its vocal-nasal tract. The longer the tube the sound passes through, the lower the frequency of the sound becomes. Female koalas seem most interested in the lower frequencies, which belong to the largest males.





"... the size of the male koala only accounts for about one-third of the variability in a male's siring success."

This only tells part of the story, because a genetic analysis of our population revealed that the size of the male koala only accounts for about one-third of the variability in a male's siring success, with some small males producing more offspring than their larger contemporaries. In addition, females tend to breed with different males each year, so size is not everything. Furthermore, we never found a wild male koala that sired more than three young in any season, regardless of his size. Why is this?

For females it may be as important to know who is out there as it is to know how big he is. For males, paying attention to size is probably more important!

So we figured that the bellow was serving two different purposes: letting males know where they could and couldn't go, and letting females choose mates from a distance.

Our thoughts were confirmed when we included the proximity data into the mix, which revealed that males avoid one another most of the time. Even in the breeding season between September and March they didn't have much to do with one another.

Koalas are presumed to be solitary animals, and when many koalas are found in one tree it is considered an unusual event. However, our data suggest that females are frequently in contact with each other, from short stays in the same tree right up to multi-tree associations over several days.

We know from daytime observations that females are more tolerant of their own relatives in their range. Their ranges might overlap but they don't seem to be in the same tree very often, or even share the same tree much. It's like the black and white

squares on a chequerboard, with one koala avoiding trees that are used by the other.

Because our new technology monitors the koalas 24 hours per day, we gathered a slightly different picture. While males are very good at avoiding one another, the females seem quite tolerant of other females in their area.

But herein lies our next quandary. We assume that two males will be aggressive toward one another and therefore avoid contact, but what if the females are actually competing for trees and mates, and that is why we see so many contacts between females? We don't have an answer for this yet, but we are working toward it.

What is clear is that the information contained in the koala bellow is critical to help females to find mates and for males to remain safe in the treetops. Thus noisy human suburbs can disturb communication among groups of koalas. Indeed road noise is of low frequency, and the sound of some vehicles and machinery may well confuse koalas in their search for mates. We used to think that it was the young dispersing males that were at most risk of road injury in urban populations, but if the females are searching for mates then they are also at risk.

Across Queensland there are many isolated, small and even extinct koala populations. Our goal has to be to find, connect and protect these habitats and facilitate their repopulation. If we don't know what factors lead to successful mating seasons for the koalas, we don't have a great chance of long-term success.

Bill Ellis is a Research Fellow in the School of Agriculture and Food Science at The University of Queensland.

All Creatures Great and Small

SI-CHONG CHEN & ANGELA MOLES

Many large animals are rare or under threat, so the discovery that they ingest and disperse both large and small seeds has widespread ecological consequences.

It's estimated that more than 90% of the plant species in tropical rainforests rely on animal ingestion to disperse their seeds. Some seeds may even need to be processed by the animals' digestive tracts to be able to germinate.

You might think that larger creatures would gulp down bigger chunks of food. This idea had long been accepted by scientists studying seed dispersal, leading to the assumption that larger fruit-eating animals generally ingest larger seeds than smaller animals. This idea has been supported by studies of some animals, including fruit-eating birds and bats, but do these positive patterns hold true at a broader scale and across diverse taxa?

We have compiled data from thousands of scientific papers and amassed a worldwide database of 13,135 animal–seed interactions from all vertebrate groups, including 224 species of mammal, 313 species of bird, 42 species of reptile, one species of amphibian and seven species of fish.

The smallest seed-ingesting animal in our dataset was the Chatham Islands skink, which only weighs 3.3 grams. The smallest seed in its diet comes from a type of mountain snow-

berry. In contrast, the largest seed in the African elephant, which weighs nearly 4 tonnes, comes from an African tropical tree and is 9 cm long.

The South American tapir, which weighs more than 200 kg, transports the greatest number of seed species (more than 350 species). And giant Galapagos tortoises can hold seeds in their guts for up to 33 days. Because of the movement of the tortoises during this time, the seeds they consume may be dropped so far away that the seedlings colonise new habitats.

There were also some surprises in our dataset. Species you might not have thought of as seed dispersers, such as armadillos and even some Amazonian fish, actively ingest and disperse seeds. The only amphibian that ingests seeds is a tree frog found in tropical America, and it ingests the seeds of five plant species.

Our most surprising finding was that larger animals generally swallowed smaller seeds (Fig. 1). While this contradicts traditional ecological thinking, we can understand this counter-intuitive result by looking more closely at what different types of animal are doing.

In many groups, including birds, bats, carnivores, marsupials and lizards, larger animals tend to ingest larger seeds. Ungulates such as rhinoceros, zebras, peccaries, deer and buffalos are a clear exception to this trend, with larger animals actually ingesting smaller seeds rather than larger seeds.

One problem with previous thinking about seed ingestion was that scientists tended to focus their attention on fleshy fruits, such as berries, that are actively sought by small fruit-eating animals. However, we found that nearly one-third of the seed species ingested by animals are not fleshy, such as the seeds of grasses and daisies. These dry seeds may be eaten unintentionally during grazing or browsing. Many large animals, such as ungulates, ratites and giant tortoises, are herbivores that feed on a variety of plant materials. Our data show that small and dry seeds are often accidentally mowed by large animals grazing in grasslands and herb fields.

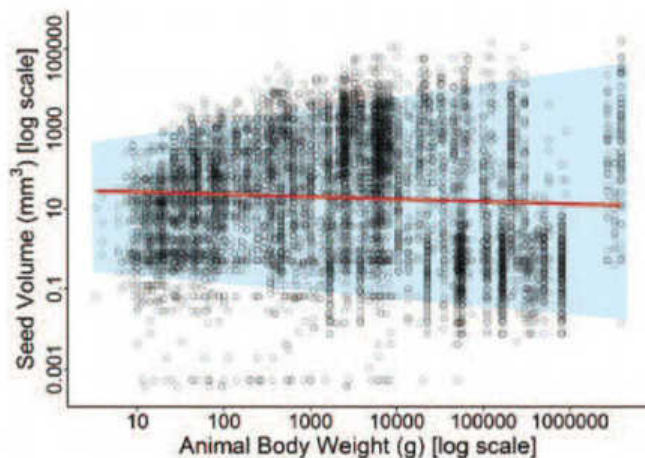


Figure 1. Contrary to traditional assumptions, there is a negative correlation between animal body weight and the size of seeds ingested (red line). Large animals ingest both small and large seeds, as 90% of the data lie in the blue-shaded part of the graph.



While it's true that large animals feed on some large seeds from fleshy fruits, we shouldn't overlook the fact that large animals, especially ungulates such as rhinoceros, zebras, peccaries, deer and buffalos, also unintentionally vacuum up huge amounts of small, dry and inconspicuous seeds as they browse on short grassy vegetation. These interactions are the primary factor that drives the negative relationship between animal body mass and ingested seed size across all vertebrates. Photos: Si-Chong Chen

Further analyses of the relationship between animal body size and the size of seeds ingested emphasised the importance of large animals as seed dispersers. Larger animals fed on a greater diversity of seed species, with larger maximum seed sizes and smaller minimum seed sizes (Fig. 1).

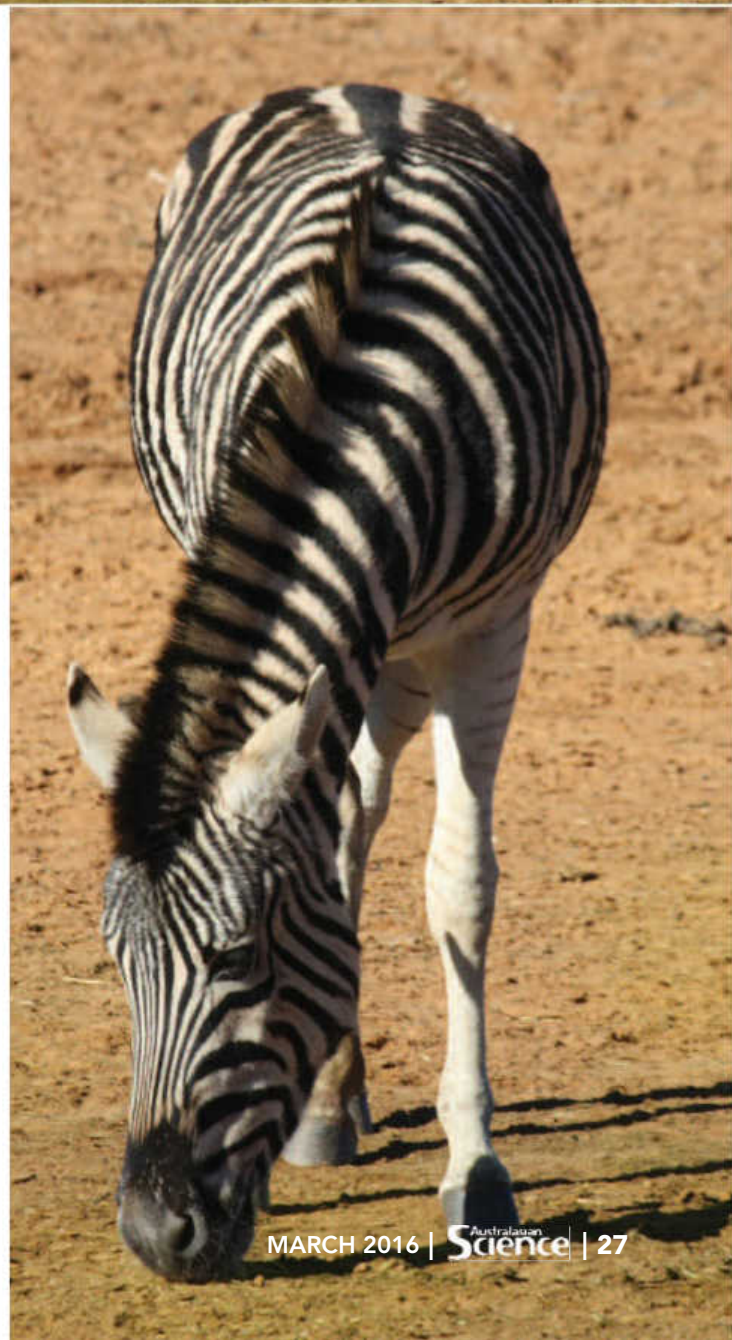
Many large animals are currently rare or at imminent risk of extinction because of poaching, habitat loss and other human activities. If we lose these large animals, both the largest-seeded species and the smallest-seeded species may lose their seed dispersers.

Since larger animals usually have larger home ranges, the opportunities for seeds to be dispersed further may be compromised if they can't hitch a ride in the digestive tracts of larger animals. This could be particularly important in the current context of climate change, which already has many researchers wondering whether plant species will be able to migrate quickly enough to track their optimal growing conditions.

Our study has corrected our understanding of the interactions between fruit-eaters and the seeds they spread. It turns out that the old theory only holds true for small- to medium-sized animals that actively seek seeds with fleshy fruits.

Science is self-correcting, even for simple and seemingly obvious "common sense" knowledge. From knowledge to wisdom, the avenues of long-held assumptions need to be constantly tested.

Si-chong Chen is a PhD candidate supervised by Angela Moles in the Evolution & Ecology Research Centre at The University of NSW.



Welcome to the Anthropocene

WILL STEFFEN

Say goodbye to the Holocene. Later this year a new epoch might be formally recognised.

The Palaeocene, the Oligocene, the Eocene, the Pliocene, the Pleistocene and, most recently, the Holocene are time periods marking significant changes in the evolution of the planet, all the way from its beginning about 4.6 billion years ago to the present. Often these periods mark changes in the biosphere, such as the evolution of multicellular organisms or the extinction of the dinosaurs, or changes in the climate, such as the swings between “icehouse” and “hothouse” conditions.

These changes have been driven by the internal dynamics of the Earth itself, such as plate tectonics and the evolution of life, but also by extraterrestrial factors such as large meteorite strikes or changes in the orbit of the Earth around the Sun. This brings us to the idea that a new epoch has commenced.

The Anthropocene is different because it is being driven by the myriad activities of our increasingly globalised human society. This means that the concept of the Anthropocene is immediately beyond the expertise of natural scientists alone, attracting increasing attention from social scientists and humanities scholars as well as the public at large.

There is nevertheless a strong natural science basis to the Anthropocene, drawing primarily from two broad areas of the sciences – stratigraphy and Earth System science.

Stratigraphers are the timekeepers of planet Earth, so theirs is a very old art. Using a wide variety of tools to interpret the rock strata of the planet, going back to nearly 4 billion years ago, they have devised careful rules to determine whether or not a new time period can be determined. Two of the most important of these rules are that:

- the rock strata above a proposed boundary are distinctly different from those below; and
- the distinction is globally synchronous, indicating that the change is global and not merely regional in character.

The Anthropocene is challenging because it is emerging as it is being studied rather than being a sharp distinction in the rock strata of the distant past. Nevertheless, stratigraphers have made remarkable progress in identifying markers character-

istic of the Anthropocene in today’s emerging strata. These include plastics, concrete, aluminium, radionuclides and spheroidal carbon particles originating from the burning of fossil fuels. All of these markers are undeniably of human origin and are widespread around the planet.

All of these stratigraphic markers begin to appear in significant amounts around the middle of the 20th century, and they are globally synchronous, appearing everywhere around the planet at approximately the same time. “Significant amounts” might be an understatement; the amounts of these new materials released into the planetary environment are staggering.

The total amount of concrete that humanity has produced, most of it in the post-1950 period, amounts to about 1 kg/m² across the entire surface of the Earth. The amount of plastic wrap produced since 1950 is enough to cover the entire planet in plastic. Enough aluminium foil has been manufactured to wrap the continent of Australia.

Humans and our domesticated animals, such as cattle, sheep, pigs and chickens, now account for more than 95% of the mass of all vertebrate animals on land, while wild animals account for only 3%. Humans alone account for ten times the mass of all of the wild animals on all continents put together.

The developing deposits resulting from the extraordinary amount of new material produced by humans meet the stratigraphic criteria for a new time period in the Earth’s history. Based on these data, a case for formalising the Anthropocene will be put to the International Commission on Stratigraphy later this year at its conference in South Africa. At present, the Anthropocene, although very widely used, remains an informal term.





Mopic

The current proposal for a new geological epoch called the Anthropocene arose from the Earth System research community, which has independently been accumulating evidence for the emergence of the Anthropocene for about 15 years. According to the Earth System approach, the Earth is a single complex system that exists in well-defined states with transitions between them.

The most recent geological epoch – the Holocene – is a well-defined state of the Earth System that has followed on from the most recent ice age. The Anthropocene represents a destabilisation of the Holocene state – accelerating change in the climate, rapid loss of biodiversity, massive disruption of nitrogen and phosphorus cycles that is polluting lakes, rivers and the coastal zone, the creation of an ozone hole over Antarctica, and so on.

Put simply, Earth System scientists have amassed an enormous amount of data showing that human activities are driving the global environment out of its stable Holocene state.

Not surprisingly, the Earth System data have also shown a dramatic increase in our impact on Earth System functioning since the mid-20th century, a phenomenon that has been dubbed the “Great Acceleration”. This is where the social scientists and humanities scholars come in.

Although it’s tempting to suggest that the Anthropocene started with the beginning of the Industrial Revolution, other changes were at least as important as the technology of the Industrial Revolution itself. These analyses emphasise the importance of two world wars and a great depression in breaking down old feudal institutions, building new institutions based on neo-liberal economic principles, the post-World War II rise of science and technology, and the acceleration of globalisation from the mid-20th century. This sharp discontinuity in socio-economics ultimately triggered the Great Acceleration and ushered in the Anthropocene.

There are other significant socio-economic implications of the Anthropocene. Although natural scientists often lump all humans around the planet into one “humanity-as-a-whole”, this generalisation masks important inequities within and between countries. Focusing on these inequalities, some humanities scholars have asked: “Which humanity is responsible for the Anthropocene?”

The answer to that question is startling. Ultimately, the changes to the global environment that mark the Anthropocene are driven by pressures arising from human consumption of goods and services and the technologies that produce them – the engine room of the post-World War II economy. Splitting “humanity” into only three groups – the wealthy OECD countries, the rapidly emerging countries of China, India, Brazil, Russia and South Africa (BRICS), and the rest, mainly poor, countries unmasks some fascinating trends.

Population growth since the mid-20th century has been dominated by the BRICS and the poor countries (primarily the latter), while the global economy remains dominated by the OECD countries despite the recent economic rise of China. In 2010 the OECD nations accounted for only 18% of the global population but generated 74% of the world’s GDP, and with it accounted for the vast majority of the consumption that is the primary driver of the Anthropocene.

The Anthropocene is only beginning, and its final length and significance isn’t known. So the advent of the Anthropocene raises the ultimate question: where on Earth are we going?

Will Steffen is Emeritus Professor at The Australian National University, and Councillor of the Climate Council of Australia.

Scanning for Empathy

ROBERT ERES

From the reassuring psychologist to the panicked parent, we experience empathy for others in different ways. Brain scans have revealed why.

Our ability to live as social creatures relies on our capacity to share and understand the feelings and thoughts of others. This is commonly referred to as empathy, and it can occur on three levels (see box, p.31):

- cognitive empathy, where we consciously recognise another person's perspective;
- affective empathy, where we relate emotionally to another person's feelings; and
- emotional regulation, where we hold our natural feelings in check and provide compassionate support for another person.

Our group at Monash University has found that there are physical changes in the brain according to whichever type of empathy dominates a person's mindset.

Understanding how and why people are empathic is a difficult task. We can't just look at how a person behaves empath-

ically because we know that there are inherent biases that come into play. While a person may not physically show empathy towards somebody that they don't like, we cannot rule out that their brains haven't responded empathically. Indeed, it is very difficult to show this through behaviour alone.

Hence we need to look inside our heads to the most complex organ in the human body, the brain. The difficulty with studying the brain is that we need special tools and machines to measure its activity, and then we need to infer from this activity how it affects behaviour.

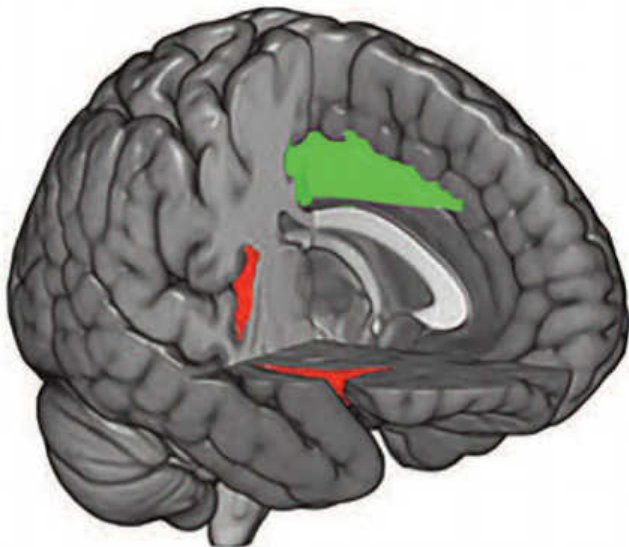
An abundance of research has shown that the brain functions differently for different types of empathy being expressed. What has been less investigated is whether the physical structure of the brain is different for cognitive and affective empathy.

We already know that the brain changes in response to repetitive mental or physical tasks, so we decided to investigate whether functional differences observed in cognitive and affective empathy were underpinned by physical brain differences.

Our results revealed that there are differences between cognitive and affective empathy. Those who were more cognitively empathic had more brain matter in the dorsal medial prefrontal cortex – a part of the brain associated with understanding people's mental states. We also found that people who were more affectively, or emotionally, empathic had more brain matter in the insula, an emotion-processing hub of what social neuroscientists call the social brain.

Measuring Empathy

We decided to limit our focus to cognitive and affective empathy. We began by finding a reliable and valid measure of these psychological constructs. It was important to find a measure that could compare each component of empathy, so we admin-



Areas of the brain associated with higher scores of cognitive and affective empathy. The midcingulate cortex and adjacent dorsomedial prefrontal cortex (green) was associated with higher scores on the cognitive empathy measure. The Insula (red) was associated with greater scores on the emotional empathy measure.



Three Types of Empathy

There has been a movement within cognitive neuroscience to understand how and why people express empathy. As a result, what we know has increased exponentially over the past 20 years. We now realise that cognition, emotion and emotional regulation combine to give a simple empathic experience, and that this fluctuates between an automatic process and a more conscious process.

To illustrate the workings of cognitive empathy, imagine a clinical psychologist who must understand how and why people feel the way they are. By understanding the mental states of others we provide insights into why people behave in a particular fashion, and it's because of this ability that we are able to sympathise with people.

For example, if you see someone crying on the side of the street after breaking up with their partner, you can identify that the reason this person is crying as a result of the emotional distress of the situation. Indeed, brain areas associated with Theory of Mind – the ability to put ourselves in another person's shoes – are more activated in these situations.

When we consider the second component of empathy, affective or emotional empathy, we often speak about sharing the emotional state of another person. A good illustration of this is when watching a sad or scary movie. It is not uncommon for us to feel emotional when the movie's protagonist is harmed or injured in a film because brain areas associated with emotions are much more active during these times and trigger the release of hormones. It's important to note, though, that this isn't restricted to sad emotions; it also works for positive emotions.

The final type of empathy, emotional regulation, is being further examined within the neuroscientific literature. It's not hard to imagine that we can't always be empathic – indeed, in a lot of situations it goes against our goal to be empathic. For example, a paediatric surgeon operating on a child must become detached from feelings of empathy in order to act rationally and save the child's life.

Evidence has shown that brain areas associated with cognitive control and executive functions are more active when we need to regulate how empathic we are. This suggests that empathy isn't always an automatic response.

istered the Questionnaire for Cognitive and Affective Empathy to each participant to determine their levels of empathy.

Once participants had completed this, we took brain scans of each participant to determine the structure of their brains, including the amount of grey matter. Pairing this information with the questionnaire scores allowed us to make inferences about how much brain matter in one specific area is associated with different levels of empathy.

When we analysed the results we found that higher scores on the affective and cognitive components of the questionnaire were associated with greater grey matter density in the insula and dorsal medial prefrontal cortex, respectively.

Conclusion

The recent findings from our lab demonstrate that brain differences in the insula and the dorsal medial prefrontal cortex are associated with how emotionally and cognitively empathic we are. It is difficult to identify, though, whether we are more empathic because we have larger brains or whether we have large brains because we are more empathic.

Regardless, we have shown that those who do express higher levels of empathy also have larger brain areas, and it's because of these social functions that we are able to navigate our complex and social world fluently alongside other people.

Robert Eres is a PhD candidate in Monash University's School of Psychological Sciences and the Monash Institute of Cognitive and Clinical Neurosciences.

The Art of Pregnancy

KIRSTY PRINGLE & KYM RAE

Low birth weight affects one in eight indigenous Australian babies. To counter this and the ongoing health issues it causes, an art program is attracting pregnant indigenous women into a research project that also educates them and monitors their health.

Preterm birth and the delivery of babies who are small at birth are common complications of human pregnancy. Not only are they life-threatening events for mothers and their babies, but they also increase the susceptibility of the baby to cardiovascular disease, kidney disease and type 2 diabetes in later life.

These pregnancy complications are at least twice as common in Indigenous Australian women. For example, rates of early onset end-stage kidney disease are up to ten times higher in Indigenous communities. As a result, the current gap in life expectancy is passed to future generations of Indigenous Australians.

Many of these diseases are “programmed” in the mother’s womb, when the mother’s health and her external environment influence the developing organs of the foetus. Low birth weight is associated with an increased risk of coronary heart disease,

hypertension, stroke and type 2 diabetes mellitus in adult life. The basis for this association is not entirely clear but it is thought that babies who are small at birth are more vulnerable to chronic disease because they have reduced function in key organs such as the kidney.

Small Indigenous babies have smaller kidneys than non-Indigenous babies of similar size. Since kidney size is correlated with the number of nephrons available in the kidney for waste filtration, individuals with a lower nephron number compensate for this by hyperfiltration, which predisposes them in later life to kidney failure. Thus low birth weight Indigenous babies are at higher risk of renal failure and hypertension, both of which are significant health issues for Indigenous adults.

The prevalence of preterm and low birth weight babies is twice as high in Indigenous women compared with non-Indigenous women (13% vs 6%). This is not surprising, as young Indigenous women often show early signs of impaired kidney function, have higher rates of obesity and diabetes, and often have poor nutrition. Other risk factors for poor pregnancy outcomes include high rates of cigarette smoking, drug and alcohol use, and high rates of infection, all of which will adversely impact on a pregnancy outcome and the long-term health of the infant.

The Gomeroi gaaynggal programs were established by The University of Newcastle to understand the developmental origins of disease in Indigenous women and their infants, and to improve birth outcomes and reduce the burden of disease. Much of the success of the research study has occurred by building a trusting relationship between the local Indigenous people and the research team through a community ArtsHealth program run by the Gomeroi gaaynggal program at a purpose-built centre.

The ArtsHealth program was developed through community consultation with the Elders, who support pregnancy health research in conjunction with health education for the community’s pregnant Indigenous women. Prior to the ArtsHealth program, the only antenatal education classes had been held in a private hospital setting, and this was considered intimidating and culturally inappropriate for young Indigenous women.

The Indigenous artists leading the art program collaborate with health professionals from the health services, private health



Gomeroi gaaynggal belly by Aunty Pearl Slater.

providers, researchers and health students. Health knowledge is imparted in an informal way while art is created by both the mothers and the health professionals, with cultural knowledge shared at the same time. The project effectively guides Indigenous families into improved health behaviours, and assists in the development of a culturally appropriate health workforce.

Health disciplines covered in the education program include dietetics, physiotherapy, mental health, sexual health, population health, obstetrics and gynaecology, women's health and child/family health. Importantly, the ArtsHealth program is facilitated by Aunty Pearl Slater, an Elder and Indigenous artist who works on artworks with the mothers each week. During their informal weekly art sessions, representatives from a variety of health areas (such as a midwife, a dietician and oral health specialist) may all attend the centre.

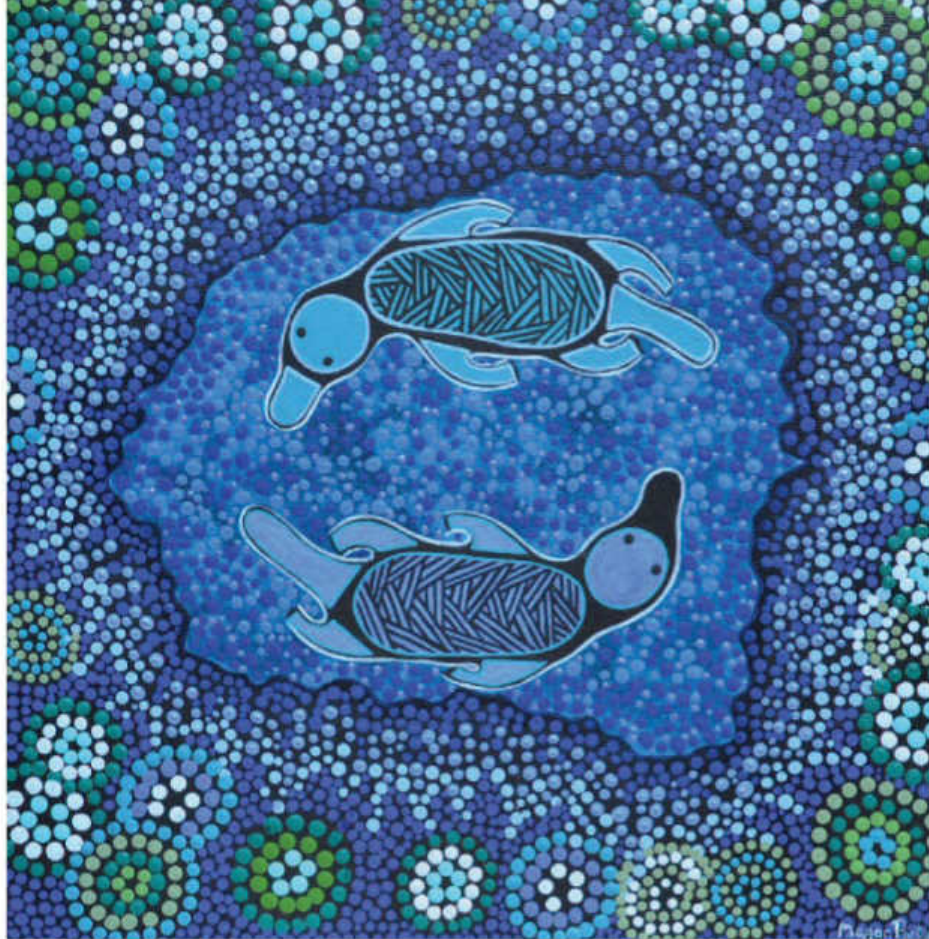
As renal disease is a serious problem for the Indigenous community, it has been a primary focus for health research and education in the ArtsHealth program. The health research is the world's largest longitudinal cohort of pregnant Indigenous women to date.

The women, who were recruited during their pregnancy by a team of Indigenous researchers, are seen a number of times during their pregnancy, soon after the baby is born, and regularly until the baby is 5 years old. At each visit the mother undergoes a number of health screens, but her renal health is of particular interest. Additionally, her pregnancy ultrasounds monitor growth of the foetal kidneys. Checking the mother's renal function continues after her pregnancy, and the infant's urine is also tested.

Becoming a part of the research study allows each mother to have many of the pregnancy-related appointments in the culturally-rich environment of the Gomerioi gaaynggal Centre, including ultrasounds and obstetric appointments. Obstetricians have reported that the Gomerioi gaaynggal program has significantly reduced the number of women who haven't undergone any antenatal care, increased the number of antenatal care visits and increased the number of women who are undertaking their pregnancy ultrasounds.

At many of the health research visits, mother share their own personal and family experiences of chronic disease, particularly kidney disease, and this has created ongoing discussions with those in the ArtsHealth program. Indigenous artists have worked with the mothers to develop their creative skills while improving their health knowledge.

One of these areas is in the area of kidney health. The Gomerioi gaaynggal team has ensured that the Centre celebrates Kidney Health Week each year, with many posters promoting strategies for keeping the kidneys healthy. The mothers helped to create a



Platypus in the Waterhole by Megan Porter, who participates in the Gomerioi gaaynggal ArtsHealth program. She says that the platypus is an important environmental indicator species for the health and state of the environment. It is only present when the quality of the water is clean as they are very sensitive to toxins. The two platypuses represent two healthy kidneys that have reached a healthy state of equilibrium within their watery environment. Through her involvement at the Gomerioi gaaynggal Centre, Megan became aware of the importance of kidney health for both the mother and baby during her pregnancy and after the birth. She wanted to pass on this message to new mothers and reflect the importance of healthy kidneys through her artwork.

poster for the front of their household fridge that includes a checklist of small changes in diet, including removing salt and soft drinks from the diet and increasing water intake.

From these small promotional activities, the Indigenous artists of the team helped the mothers to generate a range of artworks that all relate to kidney health. Many of the artworks generated through the ArtsHealth program are related to cultural stories, motherhood and pregnancy, and all create a discussion point around which community members can engage in a dialogue to promote health and well-being in the Indigenous community.

The motto of the Gomerioi gaaynggal program is "Healthy mothers grow healthy babies and healthy babies grow into healthy communities". Through the lessons learnt from the Gomerioi gaaynggal programs we are helping mothers to recreate a positive nurturing environment for their children, rich in culture with high levels of physical and mental well-being. These women are building the health knowledge of their families, encouraging them to live long, productive lives and to contribute to the culture of their communities.

Kirsty Pringle is a Research Fellow in the Mothers and Babies Research Centre at The University of Newcastle and the Hunter Medical Research Institute. Kym Rae is a Research Academic in the Department of Rural Health at The University of Newcastle, and the program coordinator for both the scientific research and ArtsHealth Gomerioi gaaynggal program.

Protein scissors that also learned to glue

JOSHUA MYLNE

An enzyme found in plants has some remarkable abilities that have drug designers excited.



Proteins are a hotly researched area of drug design, but proteins can be degraded by the human body. Protein rings, however, are super-stable, giving them greater potential as drugs.

The main way to make protein rings is by chemical synthesis, but this is costly, inefficient and uses toxic chemicals. However, we have worked out how sunflowers turn a protein string into a super-stable protein ring in their seeds.

The enzyme that performs this ring-forming reaction is one that usually cuts proteins, but instead of using water to finish

the job it uses the head of a protein chain to form a new bond instead of breaking one. The ability to develop water-based reactions will eliminate the need for expensive and harmful chemical synthesis of drugs that are stable protein rings.

The work on this unusual ring-forming reaction began with a small protein found in the seeds of sunflowers called SunFlower Trypsin Inhibitor 1. SFTI-1 is a ring of 14 amino acids that has no head or tail.

SFTI-1 was discovered in the late 1990s and became popular with synthetic protein drug designers, but only in 2011 did the

gene that encodes SFTI-1 become known. The sequence for SFTI-1 is buried inside a gene that also makes seed storage albumin, a protein that accumulates to very high levels in seeds before degrading during germination to provide nutrients for the growing seedling.

How the sequence for SFTI-1 came to be buried alongside an albumin seemed curious indeed, but recent work has found that sequences for protein rings like SFTI-1 have been buried in albumin genes for at least 28 million years. SFTI-1 is just the first known member of a very large family of tiny seed proteins.

Seed storage proteins were worked on a lot in the 1990s. Ikuko Hara-Nishimura and her Japanese colleagues found a protease called AEP that helps to assemble seed storage proteins. It transpires that the albumin and its adjacent SFTI-1 both need AEP to be assembled correctly.

A breakthrough that made it possible to study the “string to ring” reaction was the ability to make AEP properly in bacteria. *Escherichia coli* has been used in labs all around the world to make tens of thousands of different proteins, but it sometimes struggles to make certain proteins. Some proteins are toxic to *E. coli* whereas others don’t fold properly and, once extracted, are insoluble in water. Sometimes a protein can be soluble and correctly folded, but *E. coli* cannot decorate the protein with the right chemical modifications for it to be active.

Over the years, the number of engineered *E. coli* strains has continued to grow, each with different capabilities. The *E. coli* strain that enabled us to make active AEP was a new strain that was especially good at protein folding and forming sulphur–sulphur bonds, which isn’t something *E. coli* usually does well.

We used this new strain of *E. coli* to make and purify a suite of AEPs. Once we had pure AEP we changed the pH and the AEPs would self-activate by cutting themselves in several places. This self-activation by proteases is quite common.

We mixed these activated AEPs from *E. coli* with a range of protein strings containing the sequence for SFTI-1, and found that AEP uses a rather ingenious way to make a protein ring.

Proteases usually cut proteins for two reasons: enthalpy and entropy. Enthalpy refers to the energy balance of the reaction. Cutting a protein releases energy whereas forming or ligating a protein bond usually requires an energy input. Hence bond-breaking is easier to do than making one.

Entropy is about order. Cutting a protein usually gives you two proteins. It’s easier for one piece of protein to be cut into two than for two disconnected proteins floating in solution to come close enough together to be joined by an enzyme into one.

For SFTI-1 to be made by a protease, these barriers of enthalpy and entropy must be overcome.

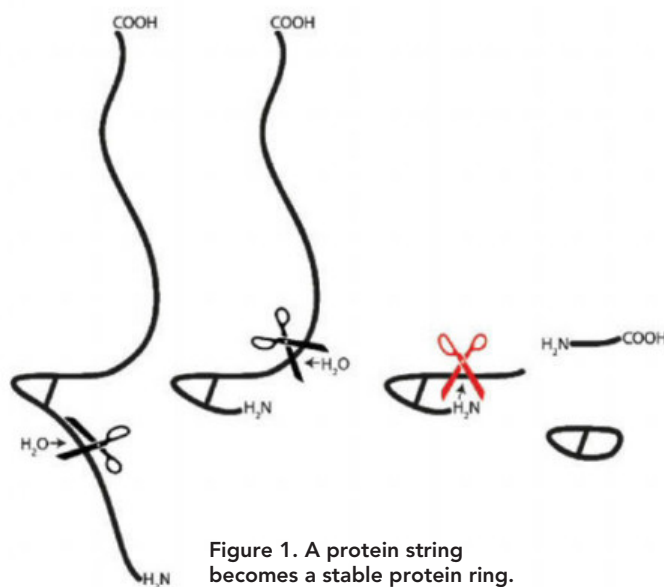


Figure 1. A protein string becomes a stable protein ring.

Proteases usually cut protein bonds by binding to the protein and then using water to hydrolyse the bond. However, water isn’t involved when SFTI-1 is made.

The SFTI-1 string is made into a ring by cleaving off and discarding a small part of the string and using a nearby amino head group (H_2N) instead of water (H_2O) to complete the reaction (Fig. 1). To overcome enthalpy and entropy, AEP uses the energy obtained from cleaving to join the head of SFTI-1 to its tail in a reaction that moves a protein bond from one place to another place that’s held really close by. The result is a circular protein with no ends.

During the same studies we found that if SFTI-1 did not get made into a ring it quickly broke down. Sealing the ends of a protein together makes it more stable, and this process has the potential to be industrialised using AEP. The ability to seal off the ends of a protein by joining them together is therefore a popular approach that protein drug designers use to stabilise proteins that would otherwise be rapidly broken down in biological fluids.

An interesting finding from our work, which has been published in *Chemistry & Biology* (tinyurl.com/j5w4sk9), was that only one of four AEPs could perform the ring-forming reaction to make SFTI-1. The other AEPs could only cut the string into two pieces of string. What was perplexing is that this bond-making AEP looked very similar to the bond-breaking AEPs.

A different ring-forming enzyme in cyanobacteria has an extra protein “wing” that helps protect the active centre of the enzyme from water, so how our bond-making AEP keeps water away from its centre must be more subtle.

Future work will attempt to understand what changes in the genetic sequence turn a cutting AEP into a ligating AEP and what changes improve its ligating ability. This should allow the engineering of artificial enzymes with superior cutting or ligating ability for industrial applications in biotechnology and protein drug stabilisation.

Joshua Mylne is an Australian Research Council Future Fellow appointed jointly to the School of Chemistry and Biochemistry & The ARC Centre of Excellence in Plant Energy Biology at the University of Western Australia.



DNA Gives Hope to Blue Whales

CATHERINE ATTARD, LUCIANA MÖLLER & LUCIANO BEHEREGARAY

A DNA study has determined whether the low genetic diversity of Australia's blue whales was caused by past natural events or recent whaling, and offered hope for their long-term survival.

Hundreds of thousands of blue whales (*Balaenoptera musculus*) were killed by whalers during the 20th century. They are the largest animal known to have existed, which made them a prime target for whaling.

Blue whales can weigh more than 160 tonnes and reach more than 30 metres long. Although immense in size, they feed only on small shrimp-like crustaceans known as krill. They require large amounts of krill to support their large size.

In winter they migrate to warmer waters closer to the Equator to breed. One population of blue whales feeds on the krill available in Australian waters in the summer and autumn, and migrates northward, likely to Indonesia, to breed in the winter.

The population feeding in Australian waters has the lowest recorded genetic diversity of blue whales in the world (Fig. 1). This population is a member of a subspecies of blue whale, the pygmy blue whale (*B. m. brevicauda*), which is smaller

than the other blue whale subspecies but can still reach 24 metres in length. The amount that their population size decreased due to whaling is uncertain.

The low genetic diversity of blue whales in Australia could be due to reduced population size following whaling or due to natural causes. We conducted a DNA study to determine which of these factors was responsible.

Human and Natural Effects on Genetic Diversity

When populations decrease in size due to human impacts such as whaling, it is more likely that genetic variation within the population will be lost. Genetic diversity declines in small populations because the few individuals that have a unique genetic variation may, by chance, not breed and therefore would not pass variation to the next generation. There is more chance in larger populations that at least one individual with a particular genetic variation will breed and pass on that variation to the next generation.

Genetic variations that are lost may be highly important to the survival and reproduction of individuals in the population. For example, the ability to cope with certain environmental conditions, such as hot weather, may be lost, which means that individuals in the population could perish during future changes in the environment.

In small populations there are also less mates available so inbreeding between relatives may occur. This can leave the next generation with a reduced ability to survive and reproduce if they have inherited deleterious genetic variations that are shared by their parents.

An alternative explanation to low genetic diversity is that a population has had or currently has a naturally small population size. Populations that are small in size due to human impacts or small in size due to natural causes are both expected to have low genetic diversity.

Natural shifts in population size and consequent shifts in genetic diversity have been seen throughout evolutionary history as the Earth's climate has changed. Some populations are also naturally small because the habitat where they are found can only support a relatively small number of individuals.

Naturally low genetic diversity is part of evolution and is not in itself a cause for concern. Instead, human causes of low genetic diversity are concerning as they may drive the extinction of populations or species.

Therefore, determining the cause of low genetic diversity is necessary for understanding whether humans have genetically threatened a population or species.

The Answer Is in the DNA

Past changes in genetic diversity leave patterns in DNA, so DNA from living individuals can be used to trace the demographic history of a population or species. This means we can use DNA from blue

whales feeding in Australia to determine the reason for their low genetic diversity. The possible reasons are a decrease in population size due to whaling, a decrease in population size due to past natural changes, or a naturally small and unvarying population size.

A decrease in population size due to whaling would generally show no or very few new genetic variants, whereas a decrease in population size due to past natural changes would show new variants. This is because more time has passed in the latter case for the population size to recover and for mutations to form new genetic variants. These new genetic variants are recognisable by their rarity and similarity in DNA sequences.

A naturally small and unvarying population size will instead show genetic variants that have relatively dissimilar DNA sequences. This is because the variants have had much time to accumulate mutations and to lose, by chance, the intermediate variants.

How do we obtain DNA from a live whale to assess genetic diversity and find these patterns? From a boat we use biopsy equipment to propel a dart that collects a small amount of skin and blubber. The dart then floats on the water and we can collect it with a net. This is akin to being

pricked with a needle, and the blue whales have no or minimal response to the dart.

DNA is extracted from the collected sample and then analysed to determine and assess genetic patterns within it. We found that the blue whales feeding in Australian waters have low genetic diversity due to a natural decrease in population size rather than due to whaling or a naturally small and unvarying population size.

The genetic pattern suggested that the blue whale population decreased in size about 20,000 years ago. This estimation involves statistically rigorous analyses and is based on the concept that more rare genetic variants, and mutational differences in these variants, are expected the longer ago the population decreased in size.

The pattern in the DNA is likely due to the founding of blue whales in Australia around 20,000 years ago by relatively few individuals. These blue whales then increased in population size in Australia and areas where they breed.

Twenty thousand years is a very young evolutionary age for a population. This means that not enough time has passed for these blue whales to substantially increase in genetic diversity by accumulating mutations, so their genetic diver-

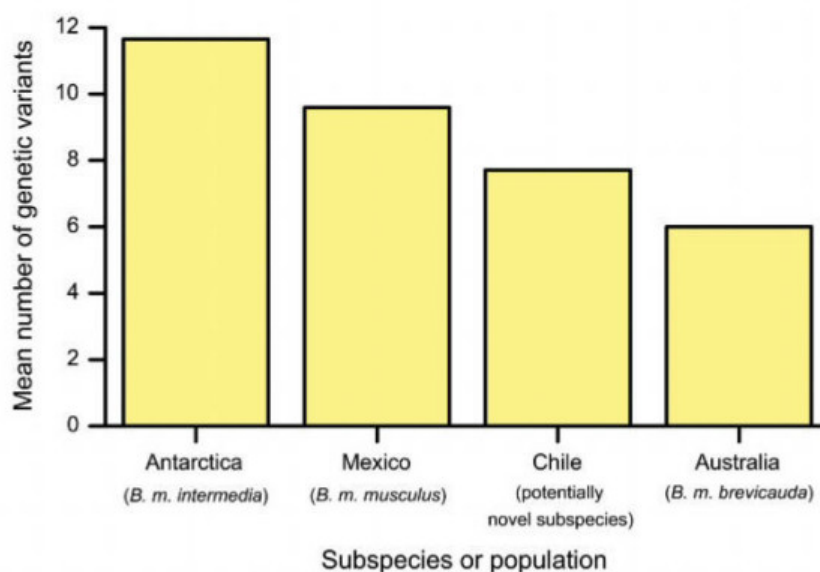


Figure 1. The genetic variation recorded for blue whales from Australia and Antarctica in this study, and from Mexico and Chile in previous studies by other research teams*.

*See tinyurl.com/gt3rbvx; tinyurl.com/j9na43h

sity remains low today relative to other blue whale populations.

We compared the pattern in the Australian blue whale DNA to patterns in the DNA of blue whales elsewhere in the Southern Hemisphere. These were blue whales that feed in Antarctica, which are a subspecies called the Antarctic blue whale (*B. m. intermedia*), and blue whales that feed in Chile, which may be a novel subspecies. We found remarkable differences among these blue whales.

We found that Antarctic and Chilean blue whales have existed for hundreds of thousands of years. This explains why they have a larger genetic diversity than blue whales from Australia; they have had a long time to accumulate mutations and therefore genetic diversity.



“... the evolution of blue whales into different populations and subspecies has been moulded by past natural climate change.”

In addition we found that Antarctic blue whales have a larger population size than blue whales from Australia or Chile. This means that Antarctic blue whales can hold, and have held, more genetic diversity than their counterparts elsewhere.

Amazingly, when blue whales feeding in Australia were smallest in their population size, Antarctic blue whales were at their largest population size. The habitat Antarctic blue whales occupied 20,000 years ago must have been able to support much greater numbers of individuals than their habitat can today. Blue whales feeding in Chile instead have apparently had a naturally constant population size over time.

A Natural Explanation

Much of the biodiversity we see today, especially in higher latitudes, has been shaped during recent glacial periods. We are currently in an interglacial period. During glacial periods, the ice sheets at the poles reached further towards the Equator and the sea levels were lower.

For some species, genetic diversity declined or was lost during glacial periods because populations contracted to refugia or became extinct. Genetic diversity subsequently increased during interglacial periods because there were increases in population size as populations expanded from refugia, or populations were founded in habitable areas and then increased in size.

To infer why blue whales came to Australia 20,000 years ago, we looked at what the climate was like at that time. Twenty thousand years ago was towards the end of the last glacial period when ice sheets were at their last maximum extent.

The Antarctic blue whale would have been forced further north at that time than they are today, as they could not inhabit ice-covered waters. Their habitat could have been spatially larger or held more krill than their habitat today, which would explain their larger population size at that time. A few Antarctic blue whales likely ventured as far north as Australia to escape the ice, and then they remained. These were the founders of the Australian blue whales.

By analysing samples from contemporary Australian, Antarctic and Chilean blue whales we were able to identify records in their DNA that attest to this hypothesis. In doing so, we provided evidence that the evolution of blue whales into different populations and subspecies has been moulded by past natural climate change.

Hope for Blue Whales in Australia

We now know that the low genetic diversity of blue whales feeding in Australia is due to natural rather than anthropogenic causes. It gives hope to the long-term survival in Australia of the largest living animal as the population has had this low genetic diversity for thousands of years.

Blue whales are currently protected from whaling but they are still recovering in numbers. Anthropogenic impacts occurring today may yet inhibit their recovery. These include marine noise, pollution and climate change.

If they don't recover they will have a smaller population size than their natural population size. Therefore they may yet have a human-caused decrease in genetic diversity.

In addition, populations with naturally low genetic diversity are likely to have less capacity to adapt to human-caused changes in the environment. With less genetic variation there is less chance that whales would have a variant that may be beneficial in future conditions, such as previously unexperienced environmental scenarios.

So while this study shows hope for blue whales, continued conservation efforts are required to mitigate the ever-increasing human impacts on their habitat and ensure their long-term survival.

Catherine Attard, Luciana Möller and Luciano Beheregaray are researchers and lecturers at Flinders University. The research has been published in the Royal Society journal *Biology Letters* (tinyurl.com/h569l8j).

Confucius Was Not a Qualified Career Adviser

Turning your hobby into your job may not necessarily lead to happiness.

We have all heard the Confucius quote: “Choose a job you love and you will never have to work a day in your life”. Steve Jobs told us all a similar message in his moving Stanford Commencement address.

The reasoning behind this is very intuitive. Most of us work around 38 hours per week – at least that’s all they pay us for – so if we could spend 38 hours per week being paid for doing the things we love doing, we would live a happy life. The problem is that it might not be so simple after all.

Self-determination theory might provide some insight into why turning your passion into your job might not always be the best option. One aspect of this theory suggests that external rewards undermine intrinsic motivation for behaviours. This may mean that earning money (an external reward) will reduce our enjoyment (intrinsic motivation) of certain activities, such as our hobbies. This suggests that if we are one of the lucky few to follow our dreams and be employed doing something we love, we might not love it for much longer.

This aspect of the theory has considerable empirical support. For instance, a meta-analysis of 128 existing studies on the topic found that external rewards can, and often do, undermine intrinsic motivation (<https://goo.gl/1urdMe>) because they change our perception of why we are doing something. When external contingencies come into the situation we start to see work as a means of putting food on the table and paying the mortgage rather than doing it for its own intrinsic reward. This leads to us having a reduced sense of autonomy and an increased sense of being controlled, and this ultimately leads to a decline in enjoyment and intrinsic motivation to perform our once-loved behaviour. Put simply, if you turn what you love into your job, you might very well stop loving it.

This leaves us with two questions to answer. First, what makes a job enjoyable if it is not an intrinsic enjoyment? For this we need to turn to the job and work design literature, which suggests a range of things that contribute to satisfaction with jobs. These include having a variety of tasks, having autonomy, seeing the product through from start to finish, giving back to society, and providing a sense of accomplishment.

The second question goes further than that, and really underpins this whole narrative: what makes an enjoyable or worthwhile life? For this question we need to start looking toward the field of positive psychology, which approaches this existential question from a scientific perspective.

Martin Seligman, a key researcher in the area, proposes five areas that promote existential enjoyment in people’s lives: (1) positive emotions like gratitude, curiosity and love; (2) engagement (being in the present); (3) relationships of all sorts; (4) attaching yourself to something greater (e.g. a cause, a religion, your family); and (5) having achievable goals and celebrating them.



“... if we are one of the lucky few to follow our dreams and be employed doing something we love, we might not love it for much longer.”

While it’s common to hear that we need to find what we love and turn it into a job in order to be happy and live a fulfilling life, this may not really be the case. We might instead stop enjoying what we once loved, and lose an enjoyable hobby rather than gaining an enjoyable job.

Instead, to enjoy our job we need to design them in fulfilling ways. And to be happy in life we need to look to positive psychology and start working on the five areas of life that are the most important for our happiness.

Kieran Carmichael is a Master of Organisational Psychology candidate at The University of Queensland.

Gravitational Waves Detected

Australian astronomers involved in the detection of gravitational waves discuss the significance of the discovery 100 years after Einstein predicted them.

"We built the most massive scientific instruments in the world and made them so sensitive that they approach limits set by quantum mechanics. On September 14 last year they directly detected for the first time the weakest signals in the universe, gravitational waves, generated in the most violent event yet recorded – the collision of two solar mass black holes.

"The energy released in this binary black hole collision was equivalent to 10 billion billion billion times the world's nuclear arsenal. What's even more fascinating is that this event did not (and does not) emit electromagnetic waves or neutrinos. The only way to observe it was with space–time change sensors – our giant laser interferometers.

"With this detection we have shifted from the realms of theory to the beginning of a new astronomy. Hopefully this first observation will accelerate the construction of a global network of detectors."

Professor David McClelland is Director of the Centre for Gravitational Physics at the Australian National University. He is a member of the Australian Consortium for Interferometric Gravitational Astronomy (ACIGA), which contributed to the gravitational waves discovery.

"The discovery confirms Einstein's prediction that gravitational waves exist, validating one of the pillars of modern physics. It confirms that black holes exist and orbit each other in binary systems, teaching us important lessons about how stars are born and live their lives.

"Einstein's theory of relativity, which predicts the existence of gravitational waves, brings together the concepts of geometry and gravity in a wonderfully inspiring way. The sources that LIGO detects, like black holes, are the home of some of the most fascinating physics in the universe. It is very exciting to think that we now have a new and powerful tool at our disposal to unlock the secrets of all this beautiful physics.

"Gravitational waves are neither scattered nor absorbed by the material they pass through, so they let us peer right into the heart of some of the most extreme environments in the universe, like black holes and neutron stars, to do fundamental physics experiments under conditions that can never be copied in a lab on Earth. The possibilities are endless."

Professor Andrew Melatos is from the School of Physics at the University of Melbourne, and a member of ACIGA.

"Gravitational waves are akin to sounds that travel through space at the speed of light. Up to now humanity has been deaf to the universe. Suddenly we know how to listen. The universe has spoken and we have understood!

"We have opened a whole new frontier by creating exquisite and almost unimaginable technologies that have allowed us to measure vibrations as small compared with atoms as atoms are compared

to people. By measuring the smallest amount of energy ever measured, we have detected the most powerful explosion ever observed in the universe, in which three times the total mass energy of the sun was emitted in pure explosion of gravitational energy in a time of less than one-tenth of a second."

Winthrop Professor David Blair is the Director of the Australian International Gravitational Research Centre at the University of Western Australia.

"The discovery of this gravitational wave suggests that merging black holes are heavier and more numerous than many researchers previously believed. This bodes well for detection of large populations of distant black holes. It will be intriguing to see what other sources of gravitational waves are out there, waiting to be discovered."

Dr Eric Thrane is from the School of Physics and Astronomy at Monash University, and a member of ACIGA.

"The detection of gravitational waves by the LIGO consortium is one of the most significant discoveries in physics in the past century - confirming one of the key predictions of Einstein's Theory of General Relativity. Much of the Universe is governed by this famous theory of Einstein's, and with him having published it 100 years ago, 2016 is a great time to prove Einstein right.

"This discovery will also be the beginning of a whole new realm of physics - gravitational wave astrophysics. The gravitational waves that have been detected are likely to have been produced by the merger of two black holes, and that is something we've not been able to see before. The ability of ALIGO to detect gravitational waves from such dramatic events will allow them to be located in the universe and be followed up by telescopes, with any associated radiation providing vital additional information on these enigmatic objects.

"What's also really satisfying for me is the very strong involvement of Australian physicists and astrophysicists in the development of gravitational wave detectors and this very first detection – most notably David Blair's Group at the University of Western Australia and David McClelland's team at the ANU."

Warrick Couch is President of the Australian Institute of Physics and Director of the Australian Astronomical Observatory.

"This is an immensely important discovery for physics and astronomy. Back in 1915 Einstein proposed that space–time is a four-dimensional fabric that can be pushed or pulled as objects move through it.

"If you run your hand through a still pool of water, waves will follow in its path, spreading throughout the pool. Now that we've caught these waves, we can use them to see the universe in entirely different ways to what was previously possible."

Dr Simon Johnston is the Head of Astrophysics at CSIRO, which contributed to the research.

How Safe Is Australian Honey?

A study has reported that Australian honey has liver-damaging toxins at levels that exceed European standards. How concerned should we be?

"Plants often use toxic chemicals to stop animals eating them. One class of toxic chemicals are the pyrrolizidine alkaloids, which can cause liver and lung damage. Long-term consumption of pyrrolizidine alkaloids may increase the risk of cancer.

"Pyrrolizidine alkaloids are present in plants ranging from comfrey to Patterson's curse (Salvation Jane), and small amounts of pyrrolizidine alkaloids may be found in salads, herbal medicines and honey. In many parts of Australia, Patterson's curse /Salvation Jane is a significant source of nectar for foraging bees. This honey can have high levels of pyrrolizidine alkaloids, and must be diluted with honey from other sources to reduce the levels.

"The recent report (tinyurl.com/guq888l) shows that Australian honey has on average four times more pyrrolizidine alkaloids than European honeys. European guidelines are more stringent than Australian guidelines, mostly due to a more conservative estimate of cancer risk. While pyrrolizidine alkaloids are able to produce cancer in rats, evidence for cancer in humans is indirect. However, for most Australian honeys the risk is low.

"For a 70 kg person consuming the average amount of honey (around 3 grams per day, roughly three teaspoons), consumption of most of the Australian honeys would be safe at both European and Australian guidelines. There were a few exceptions, and these are of concern. However, people who are high consumers of honey are at much greater risk, and several honeys exceed both current Australian and European guidelines when consumed at levels seen in 5% of the Australian population.

"While for the average consumer the risk is low, further investigation will be needed to understand the risk to more vulnerable groups."

Dr Ian Musgrave is a Senior Lecturer in the Faculty of Medicine, School of Medicine Sciences, within the Discipline of Pharmacology at the University of Adelaide.

"Pyrrolizidine alkaloids (PAs) are naturally occurring compounds found in Patterson's curse and in more than 600 plants that grow across most of the world's pasture lands. Complete avoidance of PAs is therefore not possible. During the summer months and particularly where other plants are water-stressed, Patterson's curse may be the dominant flowering plant available for beekeepers to use for honey production.

PAs are known to be liver toxins in humans at high intakes, and some have been shown to be carcinogenic in rodents in studies where the animals are administered the compound for their entire lifetime. In humans, liver (or other) cancer has not been associated with high-level PA exposure even where outbreaks of PA-induced liver toxicity have been of sufficient severity to cause multiple deaths due to liver failure.

Such outbreaks have only been reported in communities consuming relatively large quantities of PA-containing seeds as contaminants in their grain and where protein intake has been low, impairing normal liver detoxification mechanisms.

"Consumers would be wise to avoid honey produced solely or predominantly from Patterson's curse, which is generally only available from specialist outlets or farmers markets, and honey producers have previously been advised to blend such honey with that produced from other flowering plants to keep levels as low as possible.

"There is unlikely to be a significant human health risk from consuming normal amounts of Australian honey. Those consuming high levels of honey may wish to seek honey produced from other plants."

Adjunct Professor Andrew Bartholomaeus is from the School of Pharmacy, University of Canberra; and the Therapeutic Research Unit, School of Medicine, University of Queensland.



Faces in the Crowd

Can naturally gifted face-recognisers improve the detection of lawbreakers?

While many important justice, border and security procedures depend on accurate face recognition, prior studies have demonstrated that experienced and trained personnel may not be any better at the task than inexperienced untrained volunteers, with the performance of both groups marked by errors in matching individuals to identity documents or to previously viewed photographs. A new study in *PLoS One* (tinyurl.com/znssamk) has suggested that one solution to this problem would be to identify and recruit people to these roles who are naturally gifted at face recognition, and who demonstrate fewer errors on these tasks.

Previous studies have demonstrated significant individual differences in people's ability to recognise faces. Most of us recognise familiar faces quickly and effortlessly, even when the image in a picture or video is of poor quality or viewed from an unusual angle. For unfamiliar faces, however, it is common that performance on standardised tests is marked by high error rates, with failures to match an identity card to its bearer and to correctly reject a mismatch.

One classic study reported that participants achieved only 70% accuracy at matching good quality, full-face photographs to individuals captured on video footage taken the same day. In another study, conducted with supermarket cashiers who were asked to match identity cards to subjects, the participants failed to correctly verify whether the bearer was the owner in 64% of cases when the card was presented by someone resembling the owner. When the card was presented by someone who did not resemble the photo on the card, an error rate as high as 34% was still observed.

But experience and training do not seem to enhance face recognition abilities. In one 2014 study, researchers found that trained passport control officers did not do better than untrained lay persons at matching people to photographs.

The *PLoS One* study by Anna Bobak and colleagues at Bournemouth and Stirling universities examined whether those who perform well on standardised face recognition and memory tests also excel when required to identify or match individuals on videos similar to those available through closed-circuit television systems. The participants had individually contacted the research team as they believed they were superior to their peers at recognising and recalling faces. This was confirmed using the Cambridge Face Memory Test (tinyurl.com/plvax9p), a standardised measure of memory for faces, with all participants performing markedly above the population mean.

The experimenters sought to discover whether the advanced skills demonstrated on standardised tests would also be evident on tasks requiring examination of video footage and stills, where



faces may be presented at diverse or unusual angles and with different lighting.

The first task required participants to determine whether a face captured at an angle in a still frame taken from video footage was present in an array of ten photographs of same-sex faces depicted front-on. The target person was present in half of the 80 trials.

In the second task, participants were presented with front-on photographs of 20 faces and asked to identify these in 40 brief video clips. One of the "wanted persons" appeared in half of these clips.

The expert participants performed significantly better on both tasks than controls. On the face-matching task, the experts demonstrated an error rate of 8%, substantially lower than the 40% error rate of controls, and also reported a greater degree of confidence in their judgements. When scanning video clips for targets, the experts also performed at a higher level than controls, although the difficulty of the task produced a high error rate for both groups.

The study's findings support the long-held assumption that some individuals are demonstrably superior to others at specific perceptual tasks.

The new discovery is that the advantage observed on standardised tests appears to generalise to more practical, "ecologically-valid" tasks, similar to those required by justice, border or security personnel. That this advantage was observed in self-nominated lay "experts" suggests that the process of selecting the right personnel to perform important identification roles may be more useful than any subsequent training.

A further finding of the study was that individual variation was observed between face matching and face memory tasks. If replicated, this may suggest that some experts may be particularly advantaged in matching faces to photos, such as at passport control, while others may be better at spotting faces in a crowd, as required for security or policing among large groups of people.

A/Prof Tim Hannan is Head of the School of Psychology at Charles Sturt University, and the Past President of the Australian Psychological Society.

Solving the Mysteries of the Australian Megafauna

Two new papers have narrowed the date of Australia's megafauna extinctions as well as the cause of their demise.

The many kinds of bizarre large land animals that inhabited Australia until around the past 50,000 years are known as the megafauna. These included the largest marsupials, lizards and birds to ever walk the Earth. *Diprotodon* is the iconic poster boy of the brigade, a wombat-shaped beast the size of a rhino weighing up to 2.7 tonnes that lived right across the mainland. The biggest birds that ever lived were the dromornithids, emu-like flightless bird around 450 kg in weight and 3 metres high, but more closely related to ducks and geese. The king of the post-dinosaurian reptiles was our ancient killer goanna, *Varanus (Megalania) prisca*, which as perhaps up to 6 metres long and whose closest living kin is the Komodo dragon of Indonesia.

For some time there has been an ongoing debate about what caused the extinction of these marvellous beasts. One theory says it was entirely brought on by climate change, particularly the aridity associated with ice ages. Another theory argues it was the arrival of humans into the country, which resulted in hunting of the animals and changing of their habitat through fire stick farming. A third camp thinks it was a complex scenario that probably involved factors from both sides. In the past couple of months two significant new works have added interesting new information that affects the way we think about the megafauna's demise.

While it can be shown that many of the big, common megafaunal animals went extinct around 50–45,000 years ago, many of the rarer species of megafauna, which are known from few remains, cannot be tied to a similar tight dateline for their extinction. This is not to say they didn't exist up to this point in Australia, just that we don't have fossils in the right deposit to date their final days. Climate advocates use this as evidence that the megafauna could have gone extinct in stages, stepwise, over the past 150,000 years.

Yet absence of evidence is not evidence for absence. Indeed some archaeologist are more reserved in their opinions, holding the view that unless we find a megafauna skeleton with a human bone or artefact associated with it, we cannot ever say that humans interacted with these beasts.

A new paper led by PhD student Fred Saltr  of the University of Adelaide changes this by using a mathematically rigorous statistical reappraisal of the 659 known reliable dates for megafauna in Australia. Published in *Nature Communications* (tinyurl.com/j54ofms), it showed there was a broadly synchronous extinction of the megafauna within the first 13,500 years of their overlap with the first humans. People arrived in the



A skeleton of *Diprotodon*, Australia's largest ever living land mammal, exposed at Lake Callabonna in South Australia.

Credit: Aaron Camens, Flinders University

country about 55,000 years ago, based on a modelled age estimate from actual stone tools dated at 48,000 years old.

The data also show that the extinctions were independent of climate aridity and variability at this time. In other words it cuts out the climate change argument entirely from the discussion.

The second paper, led by Dr Gerald Grellet-Tinner and colleagues at Flinders University, smashed a long-held belief about the giant flightless bird *Genyornis*. A series of papers led by American scientist Gifford Miller, who dated fossil eggshell thought to belong to *Genyornis*, was able to show that the megafauna died out about 45,000–50,000 years ago. The new paper has cast doubt on the identity of these egg fragments, as structural analysis shows the eggs were identical to those of living megapodes (mound-builders like the Australian brush turkey). The dated eggshell fragments probably belonged to an extinct large megapode and not *Genyornis*. This implies we actually know a lot less about *Genyornis* than we thought, but still supports the evidence that a major extinction event took place 45–50,000 years ago, and this included large extinct species of megapodes.

John Long is Strategic Professor in Palaeontology at Flinders University, and current President of the Society of Vertebrate Paleontology.

We Need to Come to Terms with Unconscious Bias

Training that increases our awareness of unconscious bias is useful but insufficient.

In most situations, job interviewers try hard to be fair and treat all applicants equally. But they will probably be unaware of cognitive biases that can affect their interviewing behaviour and subsequent decision-making about the suitability of each applicant:

- in-group bias, which causes us to be more comfortable with and favour people like us – people who share the same gender, background, experience, interests or personality type;
- the halo effect, which causes us to allow the characteristics of others to affect our judgement of their other qualities (e.g. physically attractive people are more trustworthy);
- anchoring bias, which causes us to rely too much on an irrelevant piece of data or belief (e.g. one of the interviewers had previously hired a woman and it turned out badly);
- minority pool bias, which causes interviewers to evaluate more negatively applicants who comprise a minority of the applicant pool;
- confirmation bias, which causes us to notice data and information that conforms with our beliefs and to disregard any that doesn't; and
- availability bias, which causes us to grab readily available data to make decisions rather than use all available and relevant data, which will take longer to analyse.

In a common situation in engineering and science, a single female applicant among three or four male candidates starts out with an initial disadvantage, particularly if the interviewers are predominantly male. She has the minority gender among the applicants, and the biases listed above can further confuse the interviewers' judgement of the most appropriate applicant.

These factors can also be present in performance appraisals, promotions and other decisions about people. Therefore organisations need to examine in detail not just their written policies and procedures but their current practices in hiring, performance review and promotion of staff, and provide appropriate training. Some definitions may help.

- Cognitive bias is a systematic deviation from rational thinking when we make judgements and decisions, and has different causes. There are more than 150 known types of such bias.
- Unconscious bias occurs automatically, is not under our control and is triggered by our unconscious mind to make quick judgments and assessments of people and situations.
- Gender bias is the general name given to any type of bias that occurs in a situation involving gender.

Unconscious bias is reflected in prejudices and stereotypes that are deeply seated within us as a result of our genetics and



socialisation. In increasingly popular “unconscious bias training”, employees take tests that indicate where their biases are, the rationale being that if we are aware of our previously unknown biases we can train ourselves to think differently and make less biased judgements and decisions.

Unfortunately, there is little evidence that consciously realising an unconscious belief or association is sufficient to mitigate it. It may do so in some cases. Some unconscious biases can be extremely deep-seated because they are genetically inherited (e.g. in-group bias). Unconscious bias training is a good start, but the real question is what are employers doing to assist their staff to really deal with their unconscious biases and how are they addressing the conscious biases that we all have?

Most organisations that have written policies and procedures for recruitment, performance appraisal and promotion of staff believe that they manage these key processes well and that their decisions are based on “merit”, which they regard as an objective concept but is actually very subjective. Unfortunately, current data on the number of women in middle and senior positions in industry and academia in Australia indicate that these beliefs are ill-founded and that gender bias is prevalent in many such organisations.

The problem is not only due to unconscious bias, as many commentators continue to claim, but to both conscious and unconscious bias and a lack of understanding of how bias can affect our decisions about people.

Best practice would be for recruitment panels to discuss their own biases before interviewing candidates, to have at hand a description of biases relevant to recruitment, their causes and their mitigation and, after the interviews, to discuss how the panel mitigated its own biases.

How long will it take for business and academia to adopt such practices?

Dr Mark Toner FTSE is Chair of ATSE's Gender Equity Working Group. He is a consultant with Gender Matters, which advises organisations on gender equity issues.

Most Earth-Like Worlds Are Unborn

An assessment of data collected by NASA's Hubble Space Telescope and the Kepler space observatory has determined that only 8% of the potentially habitable planets that will ever form in the universe existed when our solar system was born 4.6 billion years ago.

"Our main motivation was understanding the Earth's place in the context of the rest of the universe," said study author Peter Behroozi of the Space Telescope Science Institute in Baltimore. "Compared to all the planets that will ever form in the universe, the Earth is actually quite early."

Looking far back in time, Hubble has given astronomers a "family album" of galaxy observations that chronicle the universe's star formation history as galaxies

grew. The data show that the universe was making stars at a fast rate 10 billion years ago, but the fraction of the universe's hydrogen and helium gas that was involved was very low.

Today, star birth is happening at a much slower rate than long ago, but there is so much leftover gas available that the universe will keep cooking up stars and planets for a very long time to come.

Kepler's planet survey indicates that Earth-sized planets in a star's habitable zone, the perfect distance that could allow water to pool on the surface, are everywhere in our galaxy. Scientists predict that there should be one billion Earth-sized worlds in the Milky Way galaxy at present, a good portion of which are presumed to be rocky. That estimate



An artist's impression of innumerable Earth-like planets that have yet to be born over the next trillion years in the evolving universe. Credit: ESA/NASA

skyrockets when you include the other 100 billion galaxies in the observable universe.

The last star isn't expected to burn out until 100 trillion years from now, leaving plenty of opportunities for untold more Earth-size planets to arise in the habitable zone.

David Reneke is an astronomy lecturer and teacher, a feature writer for major Australian newspapers and magazines, and a science correspondent for ABC and commercial radio. Subscribe to David's free Astro-Space newsletter at www.davidreneke.com

An Ominous View behind the Milky Way

Hundreds of hidden nearby galaxies have been studied for the first time, shedding light on a mysterious gravitational anomaly dubbed the Great Attractor. Despite being just 250 million light years from Earth, the new galaxies had been hidden from view until now by our own galaxy, the Milky Way.

Using CSIRO's Parkes radio telescope equipped with an innovative receiver, an international team of scientists was able to see through the stars and dust of the Milky Way into a previously unexplored region of space.

The discovery may help to explain the "Great Attractor", which appears to be drawing the Milky Way and hundreds of thousands of

other galaxies towards it with a gravitational force equivalent to a million billion Suns.

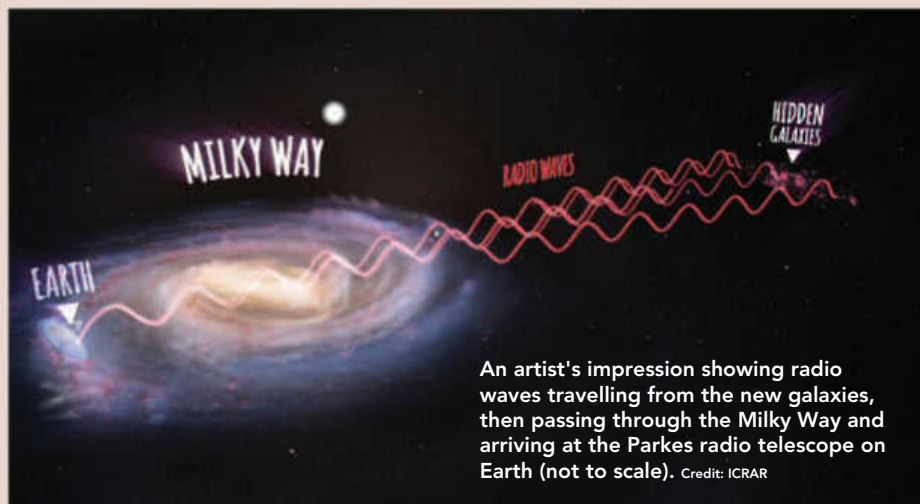
The research, published in the *Astronomical Journal* (tinyurl.com/grrg2n6), found 883 galaxies, one-third of which had never been seen before.

Prof Lister Staveley-Smith of The University of Western Australia node of the International Centre for Radio Astronomy Research said that scientists have been trying to get to the bottom of this mysterious Great Attractor since major deviations from universal expansion were first discovered in the 1970s and 1980s.

"We don't actually understand what's causing this gravitational

acceleration on the Milky Way or where it's coming from," Staveley-Smith said. "We know there are a few very large collections of galaxies we call clusters or super-clusters there, and our whole Milky Way is moving towards them at more than two million kilometres per hour."

Astronomers have been trying to map the galaxy distribution hidden behind the Milky Way for decades in an attempt to explain its movement. They've used a range of techniques, but only radio observations have really succeeded in allowing them to see through the thickest foreground layer of dust and stars.



An artist's impression showing radio waves travelling from the new galaxies, then passing through the Milky Way and arriving at the Parkes radio telescope on Earth (not to scale). Credit: ICRAR

What The Egg Industry Doesn't Want You To Know

The health claims of the egg industry rely on a red herring and a half-truth.

The egg industry has fostered widespread belief that dietary cholesterol in egg yolks is harmless. Its proposition rests on a red herring and a half-truth. The red herring is a misplaced focus on elevated fasting levels of low density lipoprotein (LDL) cholesterol as the main harmful effect of dietary cholesterol. The half-truth is the slogan: "Eggs can be part of a healthy diet for healthy people". Those at risk of heart attack or stroke should understand the issues.

The Red Herring

Dietary cholesterol and egg yolks do raise fasting levels of LDL cholesterol, but more important are the effects after meals. For several hours after a high-cholesterol, high-fat meal there are increased levels of oxidised LDL (the most harmful form of cholesterol), impaired function of the artery lining, making arteries sticky and twitchy, and inflammation of the arteries.

Longstanding recommendations that patients at risk of vascular disease should reduce dietary cholesterol below 200 mg/day are based on strong evidence that dietary cholesterol increases cardiovascular risk. A yolk of a single jumbo (65 gram) egg contains 237 mg of cholesterol, which is more than the recommended daily intake of cholesterol for those at risk of heart attack or stroke.

The Half-Truth

Egg marketers maintain that studies have not shown harm from egg yolk consumption among healthy people. This is based on two US studies that did not find such harm among those who remained healthy. However, both of those studies also showed that an egg a day doubled coronary risk among people who became diabetic during follow-up. Since the US diet is generally poor, it is difficult to show harm from egg consumption in Americans. In Greek diabetics, an egg a day increased coronary risk fivefold, and each 10 grams of egg per day (about one-sixth of a large egg) doubled cardiovascular risk. Egg consumption also increases the risk of diabetes and congestive heart failure.

Among participants in the Racial Ethnic and Geographic Differences in Stroke study, dietary cholesterol and egg consumption significantly predicted the risk of atherosclerotic events such as myocardial infarction, stroke and revascularisation.

Beyond Cholesterol

Lecithin is another important ingredient in egg yolks (~250 mg in a large egg) that causes vascular harm. Intestinal bacteria convert dietary lecithin to trimethylamine. This is oxidised in the liver to

trimethylamine n-oxide (TMAO), which causes atherosclerosis in animals. In patients referred for coronary artery imaging, high TMAO levels after a test dose of two hard-boiled eggs increased major cardiovascular events 2.5-fold in 3 years. These revolutionary findings suggest new approaches to cardiovascular prevention by manipulating gut flora with macrobiotics, or targeted replacement of harmful intestinal flora with beneficial flora.



The combination of high cholesterol and lecithin levels in egg yolks may also explain why egg yolk consumption accelerates hardening of the arteries by about 60% as much as smoking, and these effects are additive. A young man might think he can smoke and eat eggs with impunity because his heart attack is decades in the future, but why would he want to bring it on sooner?

Is It Safe to Eat Two Eggs Per Week?

One large egg yolk contains 237 mg of cholesterol, which is as much cholesterol as a 12-ounce (340 gram) burger. That's more than 4 days worth of meat in the Mediterranean diet, which is the best diet for diabetes and the prevention of vascular disease. Two eggs per week (100 per year) amounts to 400 extra days worth of cholesterol in a year.

Regular consumption of egg yolks should be avoided by people at risk of cardiovascular disease – those who expect to live past middle age. Stopping the consumption of egg yolks after a stroke or myocardial infarction would be like quitting smoking after a diagnosis of lung cancer.

Only people who know they will die of another cause can eat egg yolks with impunity. I advise my vascular patients to use egg whites, or egg white-based products to make tasty omelettes, frittatas and egg salad sandwiches.

Dr J. David Spence is a Professor of Neurology and Clinical Pharmacology, and Director of the Stroke Prevention & Atherosclerosis Research Centre at the Robarts Research Institute, Western University, Ontario, Canada.

What Is a PhD Worth?

The University of Wollongong has tarnished its reputation by accepting a PhD thesis that presents anti-vaccination dogma in place of primary evidence.

In late 2015 the University of Wollongong accepted a PhD thesis by Judy Wilyman entitled: “A critical analysis of the Australian government’s rationale for its vaccination policy”. She will now be awarded a doctorate.

There are three players in the drama: Dr Wilyman, Prof Brian Martin (who supervised the process) and the University of Wollongong (which awarded the degree).

I should start off by countering one of the criticisms that have been made of the thesis – that the research was conducted in a humanities department. This is irrelevant. It’s perfectly legitimate to investigate science from outside the world of science, and in fact most of the most famous and well-known philosophers of science were not themselves scientists.

The real criticism is that the thesis is not of the academic quality expected for the granting of a doctorate from a legitimate university.

Let’s look at the three players individually.

Dr Wilyman spent a decade working on this. I have read the thesis (well, most of it anyway: at 390 pages it is only slightly shorter than my paperback copy of Darwin’s *On the Origin of Species*), but the standard of “research” can probably be summed up by the fact that the second sentence in the abstract repeats one of the standard diversions used by anti-vaccination campaigners worldwide: “Deaths and illnesses to infectious diseases were significantly reduced due to environmental and lifestyle reforms prior to the widespread use of most vaccines in the mid-20th century”.

Dr Wilyman is and always has been an opponent of vaccines, and the thesis is merely a regurgitation of the nonsense we have been hearing forever, including conspiracy theories such as that the Australian government’s vaccination policy is informed by a conspiracy between the World Health Organisation and Big Pharma. We knew what she was going to say even before we had a chance to read it.

The “Publications in support of this thesis” include a link to a television show that quoted Ms Wilyman, with authorship attributed to Ms Wilyman (the actual author was journalist Anna Salleh), a paper in the journal *Medical Veritas* (a publication that is vehemently opposed to vaccination), a presentation at a conference run by an organisation that has run another conference specifically devoted to the dangers of radiation from mobile phones, and a couple of papers published in a journal produced by an Australian college of alternative medicine. (I couldn’t find out too much about the college because its website was blocked by my antivirus program for trying to install malware on my computer.)

As I said, I didn’t have to read far into the thesis before encountering red flags.

Prof Martin reacted to criticism of the thesis not by addressing the substance of the criticism but by accusing all critics of being bullies and crying “freedom of speech”. These seem to be special interests of his lately, and a previous paper he wrote about people bullying the Australian Vaccination Network was submitted as evidence in at least two court hearings. (In both cases the magistrate ruled that it was inadmissible.)

On the day that acceptance of the PhD thesis was announced, Prof Martin pre-emptively published a paper accusing anybody who might have something bad to say about the thesis of doing so with an ulterior motive. It is usually the job of the candidate to defend a doctoral thesis, not the supervising academic, and in any case any defence should be based on the quality of the work.

“Freedom of speech might be the fundamental freedom, but it doesn’t mean you can just make stuff up and call it research.”

By rebutting all criticism as simply being examples of bullying, Prof Martin is diverting the conversation away from where it should be going. As supervisor, he should have made a major contribution to the quality of the work but it seems that even he can’t defend it.

Yes, academic freedom requires that unpopular or disruptive views must be freely expressed, but that doesn’t mean that anything goes and that opinions and prejudices can be presented as fact without supporting evidence or, when any evidence is presented, it is selected by the firm and consistent application of confirmation bias. Freedom of speech might be the fundamental freedom, but it doesn’t mean you can just make stuff up and call it research.

The University of Wollongong is included here too. By allowing this thesis to be accepted it has tarnished the qualifications of everyone who has received a higher degree from the institution in the past and those who will do so in the future. The value of any qualification is inextricably linked to the standards set by and the reputation of the issuing institution, and the publicity surrounding this case could lead to employers to reasonably question whether a degree from the University of Wollongong has any value at all.

Peter Bowditch is a former President of Australian Skeptics Inc. (www.skeptics.com.au).

Bias in Natural Resource Management

Natural resource managers must acknowledge the presence of bias and make a conscious effort to minimise its influence in their decisions.

People in all walks of life – from town planners to judges and financial regulators – are subject to bias in their perceptions and judgements. This applies to environmental managers too. We recently explored the influence of bias in natural resource management and found that we may be able to improve our performance if we recognise these influences and work to reduce them.

Decision-makers do not always perceive things accurately. It has been shown that, in making judgments dealing with uncertainty, decision-makers are susceptible to different types of biases – beliefs that are inconsistent with reality or behaviours that compromise the achievement of objectives.

“...the tendency of project planners to be excessively optimistic... has led to some very poor decisions about major natural resource management investments.”

There is some research demonstrating a range of biases that influence people, but this has received little attention in the conservation literature. We set out to explore the consequences of these biases on natural resource management in general and adaptive management in particular.

Based on our survey of the economics and psychology literature, we explored the impacts of action bias, the planning fallacy, reliance on limited information, limited reliance on systematic learning, framing effect and reference-point bias. Each bias can have an adverse impact on our capacity to undertake effective adaptive natural resource management.

For example, the planning fallacy is the tendency of project planners to be excessively optimistic about the performance of a project that they’re developing. It’s a very common bias, and we suspect that it has led to some very poor decisions about major natural resource management investments.

A strategy to reduce the planning fallacy is to ask managers to forecast the completion time, cost or benefits for a range of comparable projects rather than a single project. This strategy, known as reference class forecasting, has been effective in reducing time and cost overruns in large infrastructure projects.

We believe that environmental managers and natural resource managers should be on the lookout for a range of common biases that have the potential to adversely impact natural resource management. Based on what we know about these biases there is evidence to expect that managers:

- are likely to undertake on-ground actions even when these are not worthwhile;
- could suffer from the cognitive illusion of being more in control of the system than they actually are;
- could be overconfident about the expected outcome of their decisions;
- may be overly optimistic about the expected completion time of the project;
- might rely on a partial set of information for decision-making even when more complete information is available;
- might rely on trial-and-error learning and repeating their past successful choices instead of collecting and comparing information about the full set of decision options; and
- could try to achieve predefined goals rather than the best possible outcomes from a project.

There are many things that can be done to help minimise the impact of bias.

First, agencies need to promote a culture of learning. It needs to be recognised that both successful and failed projects generate valuable information about the future state and expected impacts of the management interventions. This could be done by providing appropriate incentives for the managers and decision-makers to consider the full range of options before making any decision, or asking managers to justify their decisions to external parties.

Second, adoption of a decision support system could facilitate the retention and storing of relevant information. It may also make learning from past projects easier and help in systematic evidence-based decision-making. Of course, relevant staff should be adequately trained and properly incentivised to use such systems.

Third, conducting benefit–cost analyses of planned options would help to refine and prioritise the options during the design phase of an adaptive management cycle. Benefit–cost analysis provides a systematic and objective framework to include all relevant costs and benefits related to a project.

Fourth, involvement of external third-party reviewers may also help in designing more realistic and feasible projects.

Finally, scenario analysis should be conducted as part of the assessment and design phase to anticipate the expected outcomes of different options. It’s advisable to consider the likely impacts of different types of biases and the effectiveness of potential remedial measures before making any final recommendation for use in decision-making about natural resources.

Sayed Iftekhar and David Pannell are members of the ARC Centre of Excellence for Environmental Decisions. They are based at the University of Western Australia.

CSIRO Cools on Climate Science

The science of climate change might now be accepted by world governments, but it's short-sighted of CSIRO to short-change its research capabilities in this area.

The scientific community was shocked by the February announcement that hundreds of CSIRO positions will be axed. The cuts follow a steady erosion of the public science body, with more than 200 redundancies per year in recent times.

The new CEO, Larry Marshall, justified the attack on CSIRO's climate science capacity by saying that the UN conference on climate change in Paris last December meant that the science was settled. Of course, the basic science has been settled for a long time, largely because of the work done by CSIRO scientists over the 30 years since the Villach conference. But we still have a great deal of uncertainty about the scale and rate of changes that are resulting from the human impact on the atmosphere.

It's always disappointing when science is cut back, especially when we need to be more innovative to overcome the economic problem of falling commodity prices. It's particularly bad when the cuts are in such areas as Oceans & Atmosphere, Land & Water and Manufacturing, as these are all critical to our chances of a sustainable future.

More worrying than the cuts is the language used by the new CEO: there won't be scientists sacked, there will be "reductions in headcount"! And these aren't research areas, they are "business units" headed not by top scientists but "business leaders". The cuts are "something that we must do to renew our business," according to the CEO.

I fear that the government is trying to sabotage our public science body and turn it into a consulting business. I was worried this might happen when the new CEO was appointed, as his background was in venture capital rather than science.

At least one member of the lunar right on the government back bench has hailed the attack on climate science. Dennis Jensen, the member for the WA electorate of Tangney, boasted on his Facebook page that he had given what he called science advice to former Prime Minister Tony Abbott and expressed delight that the head of CSIRO was now acting to reduce public funding of climate science.

Ian Lowe is Emeritus Professor of science, technology and society at Griffith University.



CSIRO CEO Larry Marshall: "We must focus our work on areas of the most benefit and sometimes this means making some tough choices".

Three Minutes to Midnight

Each January, the US-based *Bulletin of Atomic Scientists* updates its Doomsday Clock. The annual exercise began in 1947 when concern about nuclear weapons produced a reading of seven minutes to midnight. As the Cold War intensified and more nations joined the nuclear arms race, the clock steadily inched forward and reached 11.58 pm in 1953.

Tension remained high throughout the 1970s and 1980s, despite the Nuclear Non-Proliferation Treaty, which aimed to curb the spread of nuclear weapons. Under the Treaty, the five nations that had nuclear weapons – USA, UK, France, China and the Soviet Union – agreed to reduce their arsenals. In return, the rest of the world agreed not to develop nuclear weapons.

There are different views about the Treaty's effectiveness. Critics warn there are still enough nuclear weapons to render the planet uninhabitable. India, Pakistan, Israel and North Korea now also have bombs. But those who support the Treaty argue the spread of nuclear weapons might have been worse without the agreement.

The collapse of the Soviet Union saw the clock wound back to 11.43 in 1991.

Since then things have steadily got worse. Last year, the clock moved to 11.57 pm and this year it stayed there. The report said the threat of nuclear weapons remains, and is augmented by such other risks as climate change, terrorism and cyber-threats. There are still 16,000 nuclear weapons stored at 100 sites in 14 countries. Of these, about 10,000 are in military arsenals, ready for use.

The USA, Russia and China are still modernising their nuclear weapons, with the US government recently committing more than US\$100 billion to its program. India and Pakistan are increasing their weapons stocks, while North Korea recently claimed to have tested a hydrogen bomb. And around the world, there are on average about 15 instances each year of nuclear material being recorded as lost, stolen or mislaid.

The report is significant for Australia as a uranium exporter. We export uranium to countries that have not fulfilled their obligations under the Non-Proliferation Treaty, like the USA, or that have not signed it, such as India. The modest economic return from our uranium exports is making the world more dangerous.

Royal Paternity Tested in the Modern Age

A royal paternity test in Belgium has far-reaching implications for fertility clinics.

Even when they are centuries old, royal paternity disputes are fascinating. DNA studies of the recently discovered bones of Richard III suggest that the entire Plantagenet dynasty may have been illegitimate.

During the 19th century hundreds of imposters claimed to be the Dauphin of France, the son of Louis XVI of France and Marie Antoinette who had allegedly escaped from his Republican captors. A DNA test in 2000 proved that this was false: he had died in captivity as a child.

Similar rumours circulated about Grand Duchess Anastasia, the 17-year-old daughter of Tsar Nicholas and Tsarina Alexandra of Russia. She was said to have survived a Bolshevik firing squad, and at least ten women claimed her identity. The most famous of them was finally disproved by a DNA test long after her death.

More recently the former Spanish king, Juan Carlos, fought off two paternity cases.

The latest scandal could alter long-standing legal doctrines and change the line of succession to the throne of the Kingdom of Belgium. Here is what has happened: a court in Brussels has granted a London-based Belgian artist the right to seek legal recognition of her long-standing claim that the former King, Albert II, is her real father.

Delphine Boël is the 47-year-old daughter of Baroness Sybille de Selys Longchamps, who gave birth to her when she was married to Jacques Boël, a billionaire Belgian industrialist. It appears that the Baroness had an affair with Albert before he became king, and that Delphine was their offspring.

In Belgium, men cannot be forced to take a paternity test and Albert has declined. However, Jacques Boël did have one and it proved that Delphine is not his daughter. Under Belgian law, his legal status as the father has to be revoked before another man's can be proven. But this is not legally possible under current legislation. Such a request needs to be initiated before a child turns 22 or within a year of learning that a parent is not a biological parent. All these deadlines lapsed long ago for Delphine Boël.

Has *Australasian Science* become a glossy gossip mag or is there a bioethical point to this? There is, actually. Belgium's constitutional court ruled in favour of Delphine. It declared that a child's

right to know his or her origins is more important than respecting existing family ties.

This could have far-reaching implications for fertility clinics. At the moment, the identity of Belgium's sperm donors is kept secret and children have no right to access information about their biological fathers.

This landmark case also acknowledges that the heartache of not knowing a father can be psychologically damaging. Until now, Belgian law supported the notion that socially constructed relationships are more important than genetic ties.

This is an essential justification for the fertility industry, which contends that as long as children are raised in a loving environment it does not matter whether or not they know their biological parents. The court now says, however, that genetic truth is more important than settled legal status. The key sentences read:

Even if a person were able to develop his personality without having certainty about the identity of his biological father, it must be admitted that the interest an individual can have to know his ancestry does not decrease with age, on the contrary...

In legal proceedings to establish parentage, the right of everyone to the establishment of parentage must therefore prevail in principle over the interest of family harmony and the legal security of family ties.

With this decision, Delphine Boël has only won the right to formally contest the paternity of Jacques Boël. Afterwards she will ask to have Albert II recognised as her father. Her lawyers still have plenty of work to do.

What explains Delphine's insistence? Not money. She is independently wealthy. Not royal connections. She would become 15th in line to the throne, with as much chance of wearing a crown as you and I.

The answer lies in her quirky sculptures. Her portfolio is obsessively, scarily, focused on finding her true self by finding her biological father, with titles like "I, Question", "Delphine LOVE CHILD", "Identity is Golden" and "Fuck You I Exist". Her uncertainty about her genetic heritage has left deep scars.

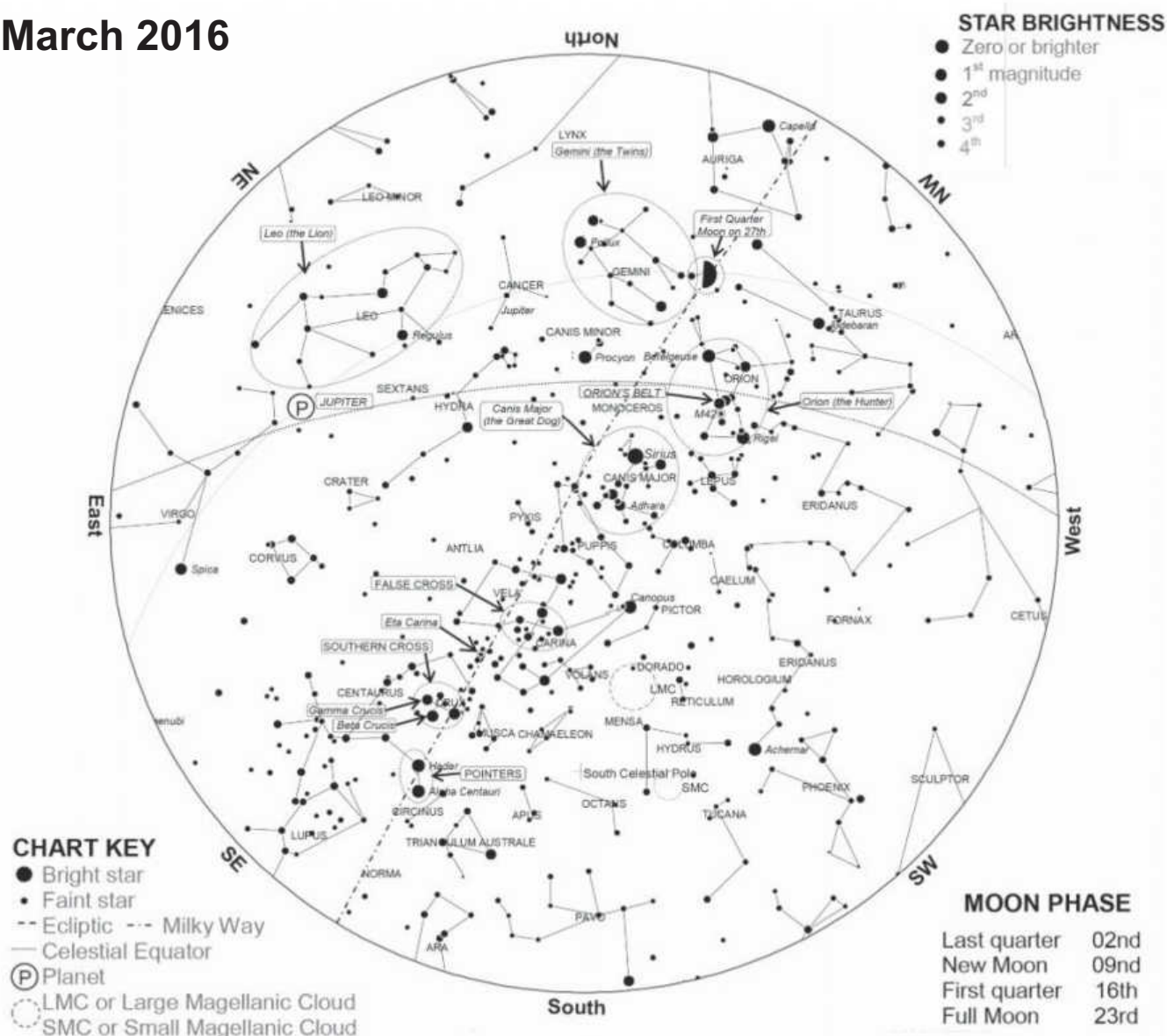
Why is she so insistent? To know who she is, that's why. For those who don't know, no question is more painful.

Michael Cook is editor of *BioEdge*, a bioethics newsletter.

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March 2016



THE CHART

The star chart shows the stars and constellations visible in the night sky for Sydney, Melbourne, Canberra, Hobart and Adelaide for March 2016 at about 9 pm (summer time) and at about 8 pm (local standard time) for Perth and Brisbane. For Darwin and similar locations the chart will still apply, but some stars will be lost off the southern edge while extra stars will be visible to the north. Stars down to a brightness or magnitude limit of 4.5 are shown on the star chart. To use this star chart, rotate the chart so that the direction you are facing (north, south, east or west) is shown at the bottom. The centre of the chart represents the point directly above your head, called the zenith point, and the outer circular edge represents the horizon.

HIGHLIGHTS IN MARCH 2016

The best time to view the Moon with a small telescope or binoculars is a few days either side of the first quarter Moon on the 16th. Jupiter, the largest of the planets in our solar system, can be seen in the eastern sky. The autumnal equinox falls on the 20th of March, when the sun crosses from the southern to the northern part of the sky. Prominent in the sky this month, are the constellations of Canis Major (the Great Dog), Orion (the Hunter), Gemini (the Twins) and Leo (the Lion). Crux (the Southern Cross) is low in the south eastern sky.

Sydney Observatory is part of the Museum of Applied Arts and Sciences. The Sydney Observatory night sky map was created by Dr M. Anderson using the TheSky software. This month's edition was prepared by B.Dew & Dr R Chhetri. © 2016 Museum of Applied Arts and Sciences, Sydney.

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